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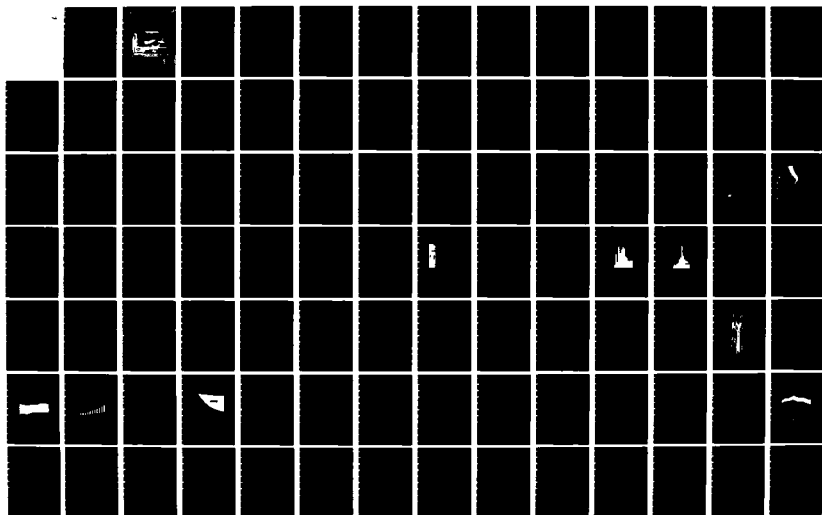
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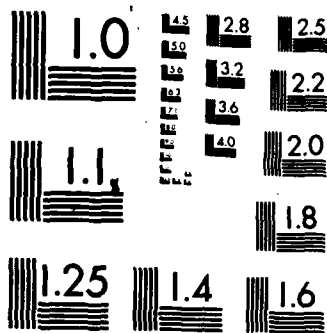
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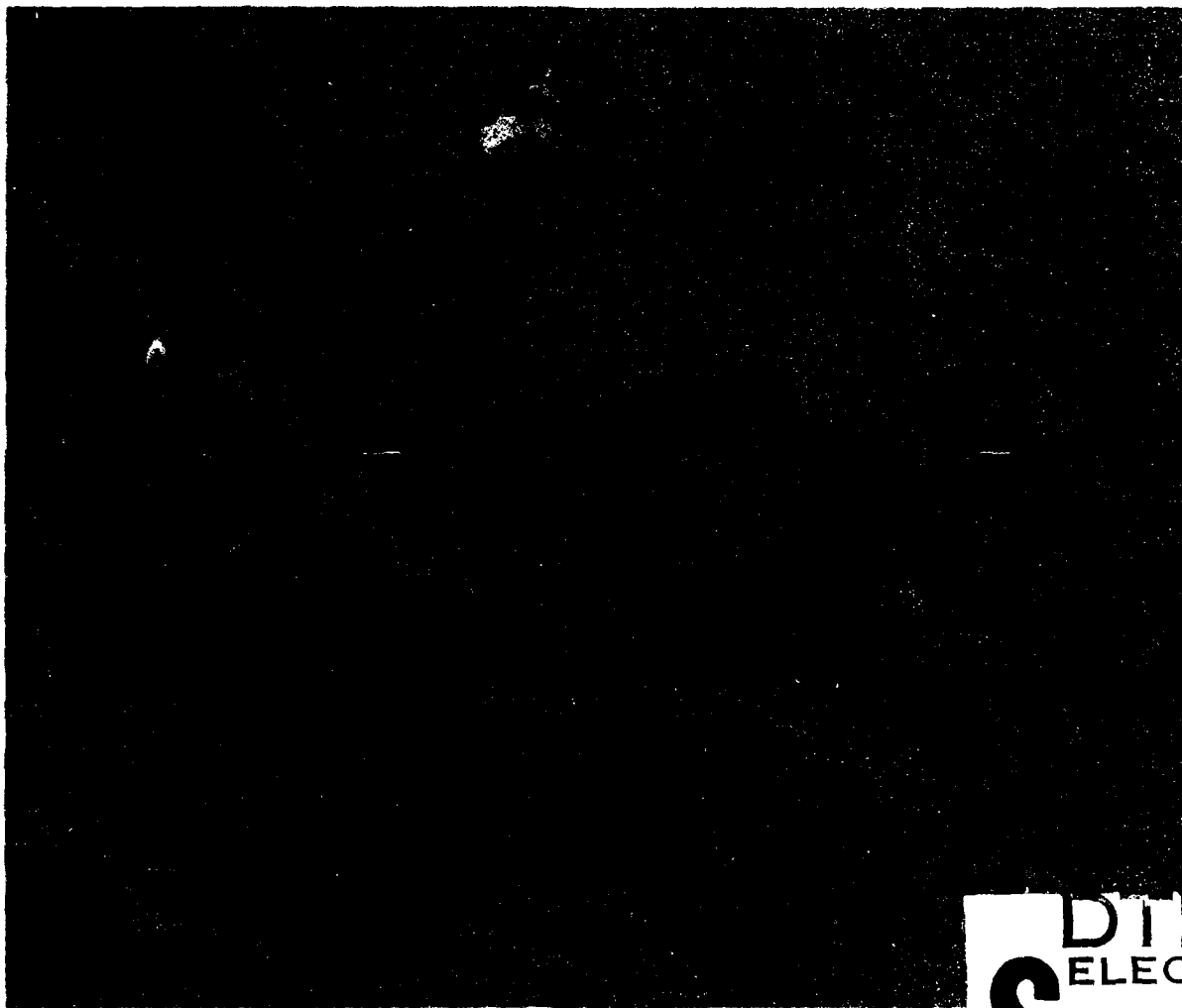


U.S. Department  
of Transportation  
Federal Aviation  
Administration

# U.S. Energy: Aviation Perspective

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and Energy  
Washington, D.C.

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AEE-5

November 1983

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<p>16. Abstract This report is a sequel/update of <u>The Impact of Petroleum, Synthetic and Cryogenic Fuels on Civil Aviation</u>, DOT/FAA/EM-82/29, June, 1982. Where the earlier report is more concerned with energy resources and availability, this report is more concerned with energy supply/demand balance and with prices. The report reviews world and U.S. energy, U.S. transportation energy, aviation fuel, natural gas, alternative fuels and energy sources, synthetic fuels, aviation fuel conservation, and petroleum price vulnerability. It draws heavily on <u>The National Energy Policy Plan of 1983</u> and its supporting documents.</p> <p>World oil production and prices should remain generally steady for thirty to fifty years, growing slightly faster than the world economy. Near-term prices should be softer. OPEC can raise prices whenever demand for its production exceeds 80% of OPEC production capacity. The U.S. could delay or reverse future price rises by encouraging, or at least reducing restrictions against, domestic production. All future energy forecasts are risky. A disruption in crude production at any time until at least year 2000, can easily increase fuel prices by 100%.</p>			
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## Introduction

The AEE-5 Fuel and Energy Work Plan was established to promote and implement conclusions and recommendations from the report DOT/FAA/EM-82/29, The Impact of Petroleum, Synthetic and Cryogenic Fuels on Civil Aviation, June 1982. (Copies of that report are now available only through the NTIS, Springfield, VA 22161). This report is expected to update the Impact report in many respects, particularly considering fuel prices and markets. The Impact report discussed some subjects largely from the resource and technical viewpoints. In energy affairs, economics and politics often dominate; this report pays more attention to those matters.

In preparing for the Impact report it was found that oil and gas will govern the world energy market for several decades and that an exhaustive accounting of alternative fuels was not justified. Volume II of Impact was therefore not written. Now, with the entire energy picture believed in better focus, more attention has been given to alternative fuels and energy sources in this report, to complete their coverage.

This report's cover illustrates perhaps the most important finding of the study to date. Even in a time of oil glut, the world remains perilously close to another 100% price rise. The author believes the U.S. can alter that unfavorable balance.

This AEE-5 program is expected to be concluded at the end of March, 1984. At that time, a brief windup report will be written to account for later events and, possibly, to further improve perspective.

## CHAPTER 1

### SUMMARY

#### World and U.S. Energy

World oil should remain generally available for at least thirty to fifty years. Real oil prices should continue to fall until 1985, when recovering U.S. and world economy may demand enough energy to stimulate a moderately sustained price rise. This rise could be delayed by stimulating U.S. production of natural gas or enhanced oil recovery. Without enhanced U.S. production, real prices of world oil in 1990 should still be lower than in 1980.

The U.S. is the single largest producer and user of energy in the world. With its reserves of oil, shale, particularly coal, natural gas and peat, as the price of world oil rises, the U.S. should continue to produce a large percentage of its energy demand from domestic fossil fuels.

The most difficult demands in the U.S. and abroad will be in liquid fuels for transportation but, if capital expenditures are made, the U.S. will continue to meet most of its needs. Taxes and regulations of various kinds are the strongest deterrents to increased U.S. production. Purchase of foreign oil and other energy forms should continue as long as their prices are lower than the total of production costs, taxes, etc. in the U.S.

The world economy has now demonstrated conclusively that oil prices are subject to supply/demand forces. Although world oil production outside OPEC has increased and demand for OPEC oil has significantly decreased since 1980, increasing world GNP is expected to increase demands on OPEC production in about 1985. When demand for OPEC oil exceeds around 80% of OPEC production capability at any time, a rise in OPEC price should be expected.

It must be emphasized that OPEC price rises may be postponed for years or decades if U.S. or other free-market production of oil, natural gas, methanol from gas or coal, or other energy is adequately stimulated. Economic studies by the DOE's Energy Information Agency indicate that a reduction of \$1 per thousand cubic feet of U.S. natural gas prices in 1985 (from \$5.50/Mcf to \$4.50/Mcf) would drop the world price of oil by \$4 per barrel (from \$37 to \$33 in 1982 dollars).

Energy conservation also plays a crucial part in the future price of world oil. After about 1990-2000, production of synthetic fuels should assist in moderating rising oil prices. But the capital costs and institutional problems of synthetic production will be large.

Coal is the most abundant U.S. energy resource and its price is

far less than for any other form of energy. Coal mineable under present economic conditions can supply the U.S. for literally thousands of years. Additional reserves can be exploited by underground gasification. Its greatest problems are in handling, shipping and environmental impacts. Some of these problems show promise of improvement. Catalytic production of synthetic fuels from coal may become economically competitive. Developments in coal technology and economics could have profound effects on world oil price and availability.

Solar and other renewable sources will require very large capital investments before they can yield significant contributions. Most of these sources are characterized by inherent limitations in continuity or reliability. Renewables are unlikely to affect world energy prices until after year 2000.

All of these comments are heavily shrouded by uncertainty and dependent on a host of international, economic, political and military events.

U.S. dependence on foreign oil imports dropped as low as 25% of our oil consumption during early 1982, but has crept back up to about one-third in the third quarter of 1983. The U.S. would probably suffer less from a disruption in foreign crude today than at any time in the future until well after 2000 (unless effective steps are taken to increase domestic fossil energy production). However, it appears that as small a disruption as 1 million barrels per day (1/5 of U.S. late 1983 imports), could triple the price of oil.

The World Energy Conference of September, 1983 was more concerned with the sociological effects of energy programs than with world energy availability and prices.

#### U.S. Transportation Energy

About 3/4 of U.S. transportation energy is used by road vehicles. Demand for auto fuel has dropped rapidly over the past five years and should continue downward, although the recent trend is toward less auto fuel conservation.

Aviation accounts for less than 10% of transportation fuel. The demand for aviation fuel should remain about constant through the remainder of the century. Its percentage of transportation fuel will rise, but only to the extent that of auto fuel will decline.

The demands for U.S. jet fuel and diesel fuel have been comparable. U.S. demand for diesel fuel has increased steadily since 1970 and it has been expected that demand would continue to rise at the same or a higher rate in the future. Heavy dieselization of U.S. autos and light trucks could immensely increase the demand for diesel fuel.

However, the outlook for future diesel fuel demand appears to

have experienced a major reversal. The past increase in diesel demand has been due to dieselization of heavy trucks. Medium trucks and all U.S. buses use a far lesser amount of fuel and are not important to major trends. The future of U.S. diesel demand depends on the popularity of diesel autos and light trucks.

DOE analysis shows that owners of new U.S. cars are now paying less gasoline real cost per mile than at any time in history. U.S. auto owners now do not respond to small differences in fuel prices, while diesel prices now rival those of gasoline. Further, new car purchase of lower-mileage models has increased relative to fuel-economic models.

Most important is the recent trend in purchase of new diesel-powered autos and light trucks. Starting in 1977, U.S. sales of diesel cars began increasing at a steady rate of about 150,000 units per year, reaching a total of over 500,000 sold in 1981. But, just as abruptly in 1982, the rate of purchases began dropping by the same 150,000 units per year. From a high of about 6% of U.S. new car purchases during 1981, in the third quarter of 1983, diesel sales dropped to 2.3% of the auto market. Probably also significant, at least one foreign manufacturer started selling diesel models at lower prices than gasoline models of the same car in the U.S.

The DOE concludes that dieselization of U.S. heavy trucks is virtually complete, of medium trucks and buses is not important, and that dieselization of autos and light trucks will not penetrate the market significantly. Accordingly, the rate of increase in demand for U.S. diesel fuel should grow at the same rate as the GNP, considerably lower than has been anticipated.

Growth of U.S. diesel fuel demand is therefore no longer expected to impact the supply or price of U.S. aviation jet fuel.

#### Aviation Fuel

As reported above, the demand for aviation fuel is expected to remain essentially constant throughout this century. This expectation is at odds with several other national and international forecasts, which expect growths of from 1% to 3% annually. The differences are probably unimportant, as far as fuel availability or prices are concerned. Among many other imponderable variables, aviation fuel demand depends on the U.S. and world economies, the amount airlines are willing to sacrifice fuel and prices in competing for passengers, and the amount of capital airlines can raise for new, fuel-efficient aircraft.

After 1985, fuel prices may rise at 1-2% faster than general inflation.

There has been unanimous agreement that the quality of world crude oil is steadily decreasing and that future oil finds are likely to be of lower quality. Over the past several years,

there has been a wide opinion that lower quality crude oil will result inevitably in pressures for lower quality jet fuel. This was particularly expected when the demand for jet fuel was projected to grow rapidly. Today there is recognition that several factors act against a trend toward lower-quality jet fuel.

First, the rapid rise in demand for jet fuel has receded and the expectation for its future growth has strongly diminished. The competition from diesel demands has certainly receded and may have disappeared. Demand for automobile gasoline has dropped so rapidly that lighter fractions of the crude barrel are becoming increasingly available. Perhaps most significant, the demand for residual fuel oil has almost disappeared; residual oil is selling at lower prices than the crude oil from which it is made.

U.S. refiners continue to shut down excess refinery capacity. The units closed are those which can only do simple processing, not sophisticated hydrogenation. A number of refiners are either making major modifications or are building new installations which will produce little or no residual oil and other heavy fractions. They will synthesize their entire output into high-quality products. As a part of this process, it becomes increasingly apparent that refiners should have no difficulty in maintaining specification quality of jet fuel. In fact, indications continue to grow that aviation may be able to improve specifications for jet fuel in the future.

At the same time, with more light fractions available from decreased gasoline production, aviation may expect to be offered fuel with lower flash points. There could be economic advantages for airlines accepting some of these fuels. FAA, NASA and others concerned with fuel specs should identify what fuel-handling and other criteria should apply to the many new jet fuels which may become available during the next few years.

#### Natural Gas

The Natural Gas Policy Act of 1978 is purported to "deregulate" U.S. natural gas in 1985. However, the Act maintains price ceilings on more than 40% of the proven natural gas in the United States. Some gas will remain at price ceilings equivalent to less than \$2 per barrel for crude oil. More important in the view of this author, these ceilings and use restrictions continue to prevent the U.S. from finding, producing and using other extensive domestic natural gas resources.

If exploited, these important domestic resources could greatly reduce U.S. demand for petroleum and, presumably, either arrest the price rise of world oil, or reverse its growth. In the opinion of this author, development of U.S. natural gas represents the most immediate, economical, and effective way by which the U.S. can stabilize its energy supply, reduce its vulnerability to crude oil disruptions, and stimulate the free

world's economy.

While the situation also may be improved by increased energy conservation, more nuclear power, and earlier synthetic and renewable energy production, none but natural gas could begin to achieve this effect in time to delay or defeat the forecast oil price rise of 1985.

Aviation, and all other interests which are substantially vulnerable to fuel availability and price, should become intimately familiar with the potential that natural gas offers to the energy market and, in turn, to all energy users.

#### Alternative Fuels and Energy Sources

Alternative fuels capable of replacing gasoline in the automotive market, could have a major effect in reducing and holding the price of petroleum low for many decades. To be successful in the automotive market, a new fuel must be available at 15-20% below the price of gasoline and must require no serious compromises.

While diesel fuel is derived from petroleum and offers no relief in the price of petroleum, it also does not appear capable of meeting the price criteria. Further, it is likely diesel engines will not be able to meet the more stringent future exhaust emission requirements, unless existing emission improvement plans are relaxed.

The most viable candidates for replacing automotive gasoline are methanol and liquid methane (liquid natural gas, LNG).

As with any other alternative fuels, both methanol and LNG suffer from the chicken-and-egg syndrome that requires a large number of fuel supply outlets before vehicles can be sold in quantity, while capital cannot be raised for the distribution system until a large number of vehicles is operating. Previously, it has been expected that new fuels could be introduced successfully through fleet operations. More recent analysis, and the U.S. experience with diesel automobiles, suggest that capture of all U.S. automotive fleets by a new fuel will not guarantee its introduction into the public market. One of the strongest obstacles today is the fact that new car owners are paying less per mile for fuel than at any time in history.

Methanol and LNG can be manufactured most readily from natural gas. But, using the ground rules of existing legislation and regulation, the DOE predicts that U.S. natural gas prices will rival that of gasoline per Btu in 1985-87. If so, the use of natural gas for methanol or LNG would appear completely eliminated. But this author stubbornly believes that U.S. natural gas prices are the result of our economic/energy policies. With natural gas reform, the 15-20% price advantage should be realized. In fact, as soon as the "natural" low price of natural gas is achieved, its effect would impact in other fuel



areas immediately, leaving the automotive fuel market for additional potential penetration.

In the world energy arena, the future of natural gas availability and price may be resolved without U.S. participation. Around the world, tremendous amounts of natural gas are being flared today and foreign oil producers are already considering converting this loss to methanol, LNG and other products. It is entirely likely that these world surpluses in natural gas will be captured and used. Its products can replace existing uses for oil as energy and chemical feedstocks and, in some areas, as fuel for ground vehicles.

This is an international potential which U.S. petroleum users should watch alertly.

Renewable energy sources do not appear capable of affecting the world fuel market until after year 2000.

#### Synthetic Fuels

It appears that synthetic fuels, particularly shale oil, can be produced at prices which nearly rival petroleum products. Unlike alternative fuels discussed above, synthetic fuels can be manufactured to the same specifications as petroleum products, or to even better specs. The only obstacles to their market introduction is their price and, today, lack of production capacity.

In late 1983, Union Oil is beginning to deliver 10,000 BPD of shale oil which has a price support of over \$40/bbl from the U.S. Synthetic Fuels Corporation. Under present arrangements, the U.S. Air Force expects to receive enough of this fuel for limited tests in daily service operations. Under current conditions, the price for this fuel to the USAF is about 10% lower than for conventional jet fuel, while the quality is higher. If this or other sources permit expanded operations, the USAF has plans for extending use of shale oil to all its domestic bases.

The DOE expects that only small quantities of synthetic fuels will become available before year 2000, but that output should increase rather rapidly after that time. By 2010 to 2020, synthetic production could begin to reduce U.S. demand for foreign oil to an appreciable degree, say two million barrels a day or more.

It is not clear if shale oil sources can be made available for U.S. domestic airlines, or whether they would presently find any advantage in cost. But this is a situation which deserves watching. Similarly, it is still unlikely that aviation jet fuel will be developed from coal at competitive prices. But a breakthrough in underground coal gasification technology or in catalytic synthesis could bring far-reaching effects.

### Aviation Fuel Conservation

The potentials for aviation fuel conservation were reviewed in the Impact report and most of them have already been exploited in U.S. airline and other aviation operations. More intensive economy can be achieved as better methods are developed for instrumenting aircraft and providing performance information. Planning and optimization methods are generally more advanced than the data inputs available for their use.

This is particularly true in flight planning and aviation weather. Flight planning methods today are highly refined, but upper-atmosphere wind data are generally no better than they were twenty or more years ago. In some respects they are worse, because they are measured less frequently today than previously.

With improved wind nowcast and forecast information, there is a direct potential for saving \$300 million per year in airline fuel costs from adverse wind data, not including costs of flight delays and diversions, or the benefits to non-airline operations.

FAA has now formally recognized the need for improved upper wind data for both its FAA Aviation Weather Plan and the Automated Air Traffic Control System described in its National Airspace System Plan. These plans will require a new national wind measurement system in 1992. The National Weather Service (NWS) also recognizes this improved weather data need for its own purposes and, depending on priorities and budgets, may be able to introduce a new system starting in 1988.

MERIT (Minimum Energy Routes Using Interactive Techniques), a combined NASA/NWS program to evaluate the effects of improved wind inputs, largely through pilot reports, will be run during the first three months of 1984. Airlines would be well advised to participate in these tests and to consider how its results can be continued or developed into regular airline flight planning.

Although the new generation of transport aircraft (B-757, B-767, DC9-80 and Airbus) appear conventional, they will provide fuel savings of 20-40%, compared to the aircraft they will replace. Future generations of new aircraft are expected to offer similar percentage improvements in fuel economy. Growth in airline fuel demand will depend to a significant degree on the rate at which these new aircraft can be introduced into service.

Aircraft used in the U.S. for commuter service have not yet adopted many of the fuel-efficient design features offered in the new large transport aircraft. But the same potential is available. In some respects, such as by using composite materials in major external surfaces, the smaller aircraft may have an earlier opportunity than larger aircraft for incorporating some drag and weight improvements. But the existing investment in conventional aircraft construction methods and prejudices in their favor will remain strong.

Petroleum Price Vulnerability

Unless the U.S. accomplishes some large and unexpected improvement in production of its domestic energy resources, this country will probably remain vulnerable to disruption in foreign crude oil supplies until well after year 2000. As the world's largest user of energy, the fate of U.S. energy and of the world energy markets are bound together. The U.S. must also be concerned about deliveries of oil supplies to its allies and trading partners, who are likely to remain vulnerable long after the U.S. achieves a greater degree of energy independence.

Pending a better assessment, U.S. foreign affairs analysts have advised that the probability for a major disruption in world crude oil supplies is about unity during any five-year period. About half of these analysts commented at the time of the Impact report that prices should rise 20-30% in a disruption, while the other half believed the price response would be 100% or more.

During a continuous international exercise by the International Energy Agency (IEA) during May and June, 1983, a hypothetical disruption allocated a one-million-barrel-per-day interruption in crude supplies to the U.S. The U.S. Strategic Petroleum Reserve (SPR) was not tapped and, in fact, continued to be filled at a rate of about 200,000 BPD. In this hypothetical exercise, the price of crude oil rose rapidly to \$98/bbl. This exercise illustrates the sensitivity of oil prices to crude oil disruptions. It also suggests that the present U.S. policy of allowing free market forces to determine the price and distribution of oil during emergencies, may be modified or amended to some degree.

The U.S. SPR has been filled to almost half its capacity and can now function as an influential factor during crude oil emergencies. The present U.S. national policy is to hold its SPR in reserve until critically required for the economy. These conditions have not yet been defined in any detail. When supplies from the SPR are made available, it is proposed that they will be distributed in response to competitive bids. Bids will be accepted from all responsible sources, including foreign bidders.

It is likely that plans for using the SPR will be actively debated in Congress, along with other tactics proposed in U.S. emergency energy plans. These debates may be delayed by more pressing legislative business, as well as by the Administration's existing proposal to revise the Natural Gas Policy Act of 1978.

SUMMARY SUPPLEMENTCSIS Conference on Oil Disruption

Georgetown Center for Strategic and International Studies' (CSIS) conference on "Oil Supply Disruption Probabilities" was held on November 10, 1984, jointly sponsored by the Department of Defense and FAA. Approximated 85 participants and observers attended and 50 submitted their numerical estimate on the probability of a severe disruption.

At this writing, the results have not been analyzed by rigorous statistical mathematics, but an approximation method has been applied. Subject to final correction, before the meeting, with 51 respondents, the mean probability for a disruption in a five-year period was given as 0.582, with a standard deviation of 0.275. This is only about half of the purely subjective poll in the Impact report, which recorded 1.0. In this CSIS poll, the range of entries was from 0.05 to 1.0.

Pending the rigorous analysis, it may be misleading to offer the distribution of entries. But it is interesting that the distribution curve shows almost a classic "head-and-shoulders" shape, with three peaks. The highest is at the mean of 0.582; the secondary peaks occur at about 0.25 and 0.75, and are about 80% of the maximum.

A second poll was taken at the close of the meeting, with 33 respondents. The mean probability dropped to 0.494, with standard deviation 0.244. The range of entries remained the same. Although numerically these results appear similar, the shape of the curve was considerably different. The shoulders disappeared completely and the curve was almost a 45° straight line from near zero to the maximum. From there it dropped toward 1.0 nearly symmetrically, but with a small residue near 1.0.

Pending CSIS's report, it appeared the participants in discussions were less concerned about the probability of a disruption than for its consequences. It was pointed out that the U.S. may remain vulnerable indefinitely, particularly through its allies and trading partners.

While Iran has made strong threats about closing the Strait of Hormuz, conference consensus was that Iran has more to lose than most if the strait is closed. The greatest concern appeared to be that a miscalculation could occur or that Iran and Iraq would raise the level of counter-threats so high that one will feel compelled to act. There is no anticipation that the war will end.

Discussion indicated that MidEast oil installations are spread so wide that they cannot be successfully defended. Defense hinges mostly on mutual self-interests and fear of retaliation. Conference opinion, including military representatives, was very strong that the U.S. cannot and will not permit the strait to remain closed. No details were offered; the statement was made emphatically and not challenged.

CHAPTER 2World EnergyIntroduction

Much of this chapter and of Chapter 3, "U.S. Energy", is taken directly from U.S. Department of Energy reports for 1983, The National Energy Policy Plan (NEPP-1983) (2-1), and its companion volume, Energy Projections to the year 2010 (2-2), for several reasons:

1. In draft form in September 1983, they are the latest projections available at this time.
2. All of the comprehensive material has been thoroughly modeled for consistency and exercised for sensitivity.
3. In addition to a base case scenario, both a high scenario and a low scenario are offered. These cases should span the most probable conditions; users may select and tailor results to their own expectations from a good orientation and with good consistency.
4. In addition to formal review of the reports within the Administration, DOE's Energy Information Administration (IEA) conducted a judgmental world price survey, submitting their projections to 54 individuals in government, associations, universities, companies and research groups. Responses were received from 35 individuals in time for inclusion in the reports.
5. The U.S. is the largest single consumer and producer of energy in the world. Its DOE has studied many elements of U.S. and world energy in great depth, improving their methods and inputs, and exposing them fully to wide distribution and scrutiny. While these predictions may stand no more probability of being fulfilled than many others, they are convenient; in some respects, they represent a degree of consensus. Since the reports are readily available, they constitute a convenient comparison base for any other energy forecasts.

This coverage develops world and U.S. energy conditions only sufficient to describe relationships which affect aviation fuel markets and prices. More serious scholars should study the references themselves for additional assumptions and techniques which may be important for their purposes. In fact, some first-hand review of these reports is valuable just to appreciate the amount of uncertainty which is inherent in any forecasting of this nature.

The past decade should have removed any doubts that energy and fuel respond to supply and demand pressures. It is difficult to project either supply or demand. The balance between them can be a fine one and, as will be shown, prices are highly sensitive to the degree of unbalance at any time. Therefore, projections of prices are necessarily both difficult and precarious. When expressed in tables or graphs, future prices tend to be regarded as firm or reliable; it must be constantly remembered that they are not.

Energy projections are usually presented as relatively smooth curves, much smoother than the history of our past decade. Forecasters point out that, as convenient as they may be, smooth trends are impossible in a free energy market. They correctly note that, when trends are projected either higher or lower than the norm that may be expected, cyclical excursions will be even greater. While the sweep of these cycles may be estimated, the time of their occurrence depends on economic, political and international events which cannot be predicted.

This report will generally show predictions as smooth curves; it will also indicate some excursions which could be expected. It even attempts to indicate effects of typical major disruptions in world oil supply. The reader must bear in mind at all times that even the basic, smooth projections are highly suspect; the excursions from smooth curves are compounding the felony.

### World Energy Trends

Most analysts agree that, barring a significant world oil supply disruption, oil prices will most likely decrease in real terms into 1985.

This conclusion is based on the fact that world demand is now well below world oil production capability and that demand for OPEC oil is currently well below 80% of OPEC production capacity. As will be shown, OPEC cannot raise oil prices when demand falls below about 80% of their capacity.

Between 1985 and 1990, depending on recovery rate of the world's economy, development of non-OPEC oil production, and numerous other factors, world oil demand should rise and the increase should largely be met by increasing demands on OPEC. Sometime between 1986 and 1990, demand for OPEC oil is projected to reach 24 to 26 million barrels per day, resuming upward price pressure on the market.

It is appropriate to halt at this point and discuss the fragility of this conclusion. In the September draft of NEPP-1983 (2-1), which is not yet released at the time of this writing, EIA is predicting that world oil prices will stabilize in the \$23- to \$30-per-barrel range in 1983 and 1984 (1982 dollars); by 1985 the price of oil should be around \$25/bbl in 1982 dollars. In 1982

dollars, the world price should therefore climb to about \$37 by 1990.

But an appreciable part of that climb from 1985 to 1990 is due to their conclusion that natural gas prices will continue to rise in the U.S., U.S. industry will correspondingly shift more energy consumption from gas to oil, and the world demand for oil will be enhanced accordingly. In the new NEPP-1984, on which work will begin in January 1984, its authors already expect that the rise in gas prices will not be so sharp as assumed in NEPP-1983, and that they are likely to project the 1990 world price of oil to around \$33/bbl, instead of \$37/bbl. The price of oil in 1982 dollars could therefore drop as low as \$20 but, more important, the price rise beyond 1990 will be considerably less than in NEPP-1983. When projected on out to 2000 and 2010, the effect is dramatic.

It is significant to note how sensitive the world oil price is to natural gas prices and usage in the U.S.! A different assumption on the price of U.S. natural gas necessarily leads to a different conclusion in world oil price. This author happens to believe that the NEPP-1984 assumed prices for natural gas may still be too high; if so, the world price of oil in 1990 could be below \$30/bbl in 1982 dollars.

Further, if the U.S. as a nation decided that it should maintain or decrease the world price of oil, it appears capable of doing so by its treatment of natural gas. In fact, natural gas is only one variable the U.S. could bring to bear. Through encouragement of enhanced oil recovery, decreased taxes on oil (including, but not restricted to the Windfall Profits Tax-WPT), and other policies, it appears that the U.S. could wrest the world oil initiative from OPEC for all time. Further, although the U.S. should be able to do this entirely through its own initiatives, with cooperation from Mexico, Canada and/or North Sea production, the job would be even easier.

In a market which has been so delicately balanced over the past decade, and will probably remain so for another twenty years, the U.S. has it within its power to continue to leave the world's oil price initiative with OPEC, or to adapt it more favorably to the Western economies.

Continuing with NEPP-1983 (which assumes high prices for U.S. natural gas), beyond 1990, "---world oil prices are extremely uncertain and speculative, but are projected in real terms to reach between \$36 and \$80 per barrel by the year 2000 and between \$55 and \$110 per barrel by 2010. By that time, however, the emergence of alternative energy sources (or technological changes that cannot be anticipated) render current projections of dubious value."

"One conditioning factor influencing the projected range of price increases during the 1990 to 2010 time period is the assumption



that the cost of unconventional oil sources such as shale oil and coal liquids will be in the \$50- to \$80-per-barrel range (1982 dollars) as opposed, for example, to the \$35- to \$50-per-barrel range assumed by NEPP-1979."

This author cannot refrain from commenting that these sources are simply another avenue by which the U.S. and OECD nations can adjust world oil prices. Editorializing further, the significant fact appears to be that the U.S. and OECD need not strive for a mythical energy independence to regain control of their energy-paced economic destiny. Only the supply/demand balance point need be controlled, not the bulk of energy supply and demand, which may lumber on, essentially unaltered.

It seems surprising that politicians have apparently not recognized that world oil prices can be controlled by controlling this relatively small "swing vote".

The remainder of this chapter is based on NEPP-1983 and its assumptions, including its high price for U.S. natural gas. (The details on natural gas are discussed later in that chapter).

#### World Oil Forecast (NEPP-1983)

World oil real prices have declined steadily since 1981, rather than climbing as assumed in NEPP-1981 and most other studies. The reasons for this decline have been: unexpectedly low demand for OPEC oil caused by tenacity of the world recession, the cyclical drawdown of world petroleum stocks, more oil conservation and fuel-switching than expected, and higher oil production outside OPEC.

EIA's history and future projection of demand and capacity for OPEC oil are shown in Fig.1. Scenario B is the NEPP-1983 baseline case (A being low and C being high). This projection may be coupled with OPEC demand/price sensitivity, shown in Fig.2 (2-3), where OPEC's responses to demands on their production capacity are shown.

There is naturally the question of whether OPEC will respond in the future as it has in the past. Since it may be assumed that OPEC has considered this type of curve in great intimacy plus all its ramifications, it may be expected that OPEC has also concluded that it is a fair representation of the world's market action.

It will be noted that 1973-74 market response has not been included in this chart---that period may be considered in the experimental phase of OPEC pricing; OPEC was still probing for the upper limit. Since then, OPEC pricing policies have been skillfully handled and the market has responded accordingly. Particularly during the past year, it has become clear that OPEC functions as the world's marginal supplier, albeit that they can supply a very large slice of the market, presently about 50% of

world production capacity in September, 1983.

That is, as world oil demand fluctuates, production by non-OPEC suppliers proceeds on about at full capacity, according to the level of oil price at any given time. OPEC production makes up the deficit demand that cannot be met by non-OPEC production. If the world demand for oil drops somewhat, non-OPEC countries continue producing at an unabated rate (most of their oil can be produced at costs below world prices) and demand for OPEC oil drops, barrel-for-barrel, with world demand.

When this drop is fairly gradual, OPEC has in the past and is likely to continue in the future, to hold the price firm in constant dollars, so that the true cost of oil drifts downward with the rate of inflation. If the demand drop is more rapid, as in late 1982, OPEC must make additional adjustments to prevent the drop in demand from depressing OPEC production and net income. Therefore, in London in March, 1983, after much struggle, OPEC finally agreed internally to drop their marker price from \$34/bbl to \$29/bbl and to hold production to 17.5 MMBD.

Accordingly, OPEC can confidently be expected to leave the price of oil at its current level, unless a further drop in world demand requires further downward adjustment. With the world economy improving and oil stocks now having been fairly well drawn down, in spite of continuing expected conservation, the world demand for oil should start to increase, reaching the point for 80% of OPEC capacity (say, 26 MMBD production of 32 MMBD capacity) at about the end of 1985 (based on NEPP-1983 assumptions). At that point, OPEC should begin again adjusting its price upward in accordance with both demand and the rate of inflation.

Readers should continue to keep in mind this fine balance between two fairly large and gross quantities, world oil demand and world oil production capacity. At least under recent and present circumstances, world oil price is dependent on the demand for OPEC production which, although large, is still a relatively sensitive quantity. As shown by Fig.2, the world price should remain stable as long as demand for OPEC oil remains around 80% of their production capacity. But 1979-1980 experience indicates that, when demand for OPEC oil reaches only 92% of capacity, the world price should rise by 50%. Then, in proceeding on to 95%, the price should have risen by 100%.

Obviously, the actual price response for an oil demand above 80% of OPEC capacity will depend on world economic, international, and emotional conditions at that time. Practically, anyone should feel free to make his own guess. But it should be evident that in the present or any future time of "oil glut", the world may never be far from another 100% price increase!

A significant disruption of crude oil production in any sector of the world is apt to trigger OPEC production demand beyond the 80%

the world is apt to trigger OPEC production demand beyond the 80% level.

Putting together the data of Figs.1 and 2, the resultant NEPP-1983 projection of world oil prices is shown in Fig.3 (2-4). The Middle curve is established as the base case, or most probable, while EIA combined a variety of inputs on the high side and the same variables equally on the low side to produce the other two scenarios shown. It may be assumed that the price of oil is unlikely to exceed the top line or drop below the bottom line, as long as the EIA assumptions are accepted.

### Uncertainties in World Oil

From NEPP-1983, "Small changes in free-world oil supply or demand can lead to large short-term oil price fluctuations. Accurately predicting the timing and magnitude of such changes or projecting the resulting short-term price responses is close to impossible."

There are two major forms of world oil price fluctuations: OPEC planned adjustments, and unexpected supply disruptions.

"Since gaining control over oil production facilities, OPEC countries have been lowering their production capacity." Fig.4 (2-2). (Note that OPEC production capacity is never expected to equal its maximum reached in 1967.) "This has lowered their costs, forced importers to use inventories to meet seasonal demand peaks (thus leveling OPEC production) and reduced the production buffer, which had helped keep prices stable for many years."

As free-world oil demand increases, OPEC can continue to bring additional capacity on line, within the boundaries indicated in Fig.4. At the same time, OPEC may increase prices to delay depletion of their total resource. It is very interesting that OPEC production can be varied over a fairly wide range without major effects on their total revenues, as seen in Fig.5 (2-2). It seems likely, therefore, that OPEC will hold production toward the low side (if they are able to agree internally) in order to decrease production problems and capital expenditures, husband reserves and, perhaps most important, maintain momentum in controlling the world oil price.

However, the world economy is never static; normal cycles must be expected and accepted. If OPEC anticipates or responds to these cycles favorably, the cycles could be dampened. If OPEC gets out of phase, the effect on world commerce could be serious. EIA illustrates the typical business cycle fluctuation compared with OPEC production capacity in Fig.6 (2-2). The question remains how OPEC responds to these cycles. If they follow the pricing behavior of Fig.2, the effect would be as shown in Fig.7 (2-2).

From valley to peak, each price rise may be as much as 75%, which

could have a serious effect on the world economy. These rises would certainly affect airlines adversely. The fact that they occur at 5-year intervals is not significant; a five-year cycle was the basis for the EIA inputs to Fig.6. EIA points out that it is impossible to predict these cycles accurately in either time or magnitude. Any serious attempt to do so, and then be wrong, could have serious consequences.

For example, suppose an oil refiner had faith in his prediction capability and planned on a four-year business cycle as the basis for his capital expenditures. If each cycle covers five years, after ten years, the predicted cycles would be 180 degrees out of phase. But cycles are not apt to occur with even spacing; a forecaster could easily be out of phase within the first cycle. So, a ten-year plan revised every year is not a cliché; it is a necessity.

"Oil disruptions can be caused by terrorist acts, wars, or political actions such as the 1973 embargo. Although no one can foresee when such disruptions will occur or their severity, we believe that the price impacts of disruptions are short term in nature with most of the effects dissipated within 5 to 10 years."  
(2-2)

EIA illustrates some spaced oil disruption scenarios in Fig.8. Each disruption is allowed to dissipate fully before the next occurs. Further, it appears to this author that the rate of price rise is less than might actually be expected, almost as though the market were fully aware and confident of the later outcome. Considering Fig.4, if OPEC is running at a normal production rate, a 5MMBD disruption over a short period would force OPEC to full production. If they respond as Fig.2 indicates, the price rise would be more like 100%.

### Probability of Oil Disruptions

As discussed in (1-1), an early 1982 informal poll of respected foreign-affairs analysts concluded that all analysts expected at least one major disruption in world crude oil deliveries in any five-year period and probably three disruptions in a ten-year period. That poll is probably not an accurate representation. A couple of analysts advise that they know of some who are not so pessimistic (as well as others who are more pessimistic). At the time of (1-1) it was not possible to investigate this question further, except to find that about half of those polled also thought the resulting oil price rise would be at least 100%; the other half opted for 30-50%.

It had been hoped that before this present report was written, it would have been possible to assemble a representative group of foreign-affairs analysts large enough to obtain a statistically significant sample, to analyze their conclusions, and to further evaluate the results. Admittedly, no matter how eminent the

sources or how reliably the data are evaluated, the results would still be based on opinion of individuals. But it was felt that a good analysis of expert opinion could be useful, lacking any better way of predicting the future.

Unfortunately, it has not been possible yet to convene this operation, although it is expected to be accomplished before the end of 1983. Because other information on energy supply, demand, prices, highway fuels and alternative energy sources came together at this time, it was concluded better to complete this report now, with the important omission of the probable threat of crude oil disruption, rather than wait for those results and decrease the timeliness of all the other information.

Therefore, results of the foreign-affairs opinions on the probability of crude oil disruptions will be reported later. However, it should be noted that no analysts have been encountered and no opinions have been heard that suggest the threat of crude oil disruption is small.

If one is considering the likelihood of catching a serious, possibly fatal disease, (as airlines might regard the effect of a serious crude-oil disruption), the exact opinion on the probability of an epidemic may not be too important. Pending further information, some degree of early immunization would seem desirable.

### Cartels

Does OPEC really operate like a cartel, as assumed in the previous discussions? Apparently the answer is, "Yes, mostly."

OPEC has availed itself of the best education and advice available. They have no doubt analyzed the situations thoroughly and have digested other significant analyses. They obviously have difficulty in acting together as, indeed, their interests are significantly divergent.

Interestingly, while there are many studies and a formal theory of monopolies, there is no organized, formal theory of cartels.

In World Energy Markets and OPEC Stability, Lexington Books, 1978, Dr. Ali Ezzati of the Brookhaven National Laboratory, modeled the total world oil supply/demand situation, including OPEC activity. He concluded that it is possible to classify OPEC members into four general categories of production and economic stature, but that these categories still leave significant differences in national objectives, which would affect actions within the OPEC structure. He concluded by modeling separately the major OPEC members and lumping together only those whose production rates cannot greatly affect price or production.

As a matter of interest, Ezzati explored both a "stability gap"

and a "destruction gap" for OPEC. His stability gap exists when demand for OPEC oil is greater than the production rate OPEC members need for their economic development programs. At the time of his study, his stability gap was calculated at about 6.6 MMBD, and one must conclude that OPEC had managed its prices and production well. Since that time, the market has switched to a destruction gap, so that OPEC has been compelled to decrease both price and, more important, production rate. The fact that world oil prices have not fallen further is an indication that, despite severe internal stresses, OPEC has managed to keep its act fairly well together, at least, so far.

The EIA and others have pointed out that OPEC has not acted differently than have other developing countries handling scarce commodities. OPEC has enjoyed a more pervasive commodity, a better opportunity for control and, despite their glaring differences, probably a fairly strong common interest. They have also had a valuable direction signal by watching spot prices in oil.

Less Developed Countries (LDCs) tend to argue that the prices of their primary goods are too low compared to the prices of manufactured goods which they must buy. For at least fifty years, LDCs have attempted to stabilize and raise the price of their goods through "commodity agreements" or cartels. In some cases, such as the diamond cartel, they have been resoundingly successful. The control of prices requires control of production or, as in the case of diamonds, holding the product off the market. At higher prices, demand is reduced, so that non-cartel countries will increase their production of the commodity, if they can, and there is more incentive for cartel members to cheat by increasing production.

"The 1973 embargo marked the final transition of Middle Eastern oil production management from international oil companies to the oil-producing nations. These nations have different perspectives and different needs than the oil companies and thus base their decisions on a different set of objectives. Further, each OPEC member has a unique combination of characteristics which cause the prices and quantities it would find most desirable to be different from the prices and quantities any other member would find most desirable. Libya, for example, has rather limited reserves, rather ambitious political objectives, and a relatively high population. This means that Libya has a high absorptive capacity for revenues. Saudi Arabia, on the other hand, has sufficient reserves to allow it to continue to sell oil well into the next century as well as a relatively low population. For Libya, there are incentives to try to maximize short-term revenues by increasing prices. For Saudi Arabia, there are incentives to keep prices at moderate levels. This would allow the Saudis to maintain their long-term market while gradually industrializing in an orderly manner. To operate effectively as a cartel, OPEC needs to convince all members that they will benefit from a cooperative effort to maintain a given price/pro-

duction level. Recently, OPEC prices and production have fallen dramatically. High prices directly and indirectly (by suppressing economic growth) caused lower demand and higher non-OPEC production than would have occurred otherwise. This resulted in lower demand for OPEC oil. For a variety of reasons, including the fact that they have the most oil reserves, a relatively low population, low revenue needs, and a desire to stabilize the Middle East and avoid invasion or revolution, Saudi Arabia has absorbed much of this loss." (see Fig.9) (2-2).

"Although OPEC has not been able to escape the problems inherent in cartels, the price of oil, in constant dollars, is over four times what it was in 1970 and is projected to increase in the future. The reason for this lies partly in the cartel, partly in the change of oil production decision-makers, partly in the change of expectations which has taken place since the early 1970s, and partly in continued global development. Under limited circumstances OPEC has had and will continue to have an effect on world oil prices...In the 1970s analysts began noting that projected oil production would soon outstrip projected oil reserve additions....Whether correct or not, such 'conventional wisdom' has an impact on the decisions of both oil users and producers as they hedge against the future." (2-2)

"Despite the tentative nature of the analysis, three significant observations can be noted: (1) regardless of the price path or the discount rate, OPEC stands to make a very large amount of money over the next 20 years; (2) prices that are continuously too low or too high result in what are considered by many analysts to be unlikely quantities of OPEC oil production (that is, less than 20 MMBD or more than 32 MMBD); and (3) OPEC revenues are not greatly affected by significant shifts in the world oil price path. This test indicates that the world oil prices resulting from our analysis are plausible in that they produce credible OPEC revenues while causing OPEC oil production to remain within reasonable limits." (2-2)

#### OPEC on OPEC

How does OPEC regard OPEC? (This section is included only for those who may be interested; it does not affect the forecast material.)

The OPEC Bulletin is produced monthly by the OPEC Public Information Department, for internal consumption and as a public-relations output to the rest of the world. It is noticeably public-relations oriented. It usually includes two to four important speeches or papers delivered at the international level; a feature article on one OPEC member country; a "Country Profile" on a non-OPEC country; and a monthly market review, discussing price developments in various world areas, together with tables and graphs of spot OPEC and non-OPEC crude oil prices for different grades and world locations; the European Market for gasoline, naphtha and distillates at Rotterdam and Italy; the US

Market; and the Caribbean, Singapore and the Gulf (Arabian) markets.

In an "Energy Talk" section, it may include summary articles on synfuels (such as the Colony Project), on gas liquefaction, or on how oil is found and produced. Its "Energy Survey" may have small reports on features such as, "OPEC Reserves to Last Beyond 2000," how bartering is being used by money-poor countries to get fuel, an oil museum in Nigeria, the Bolivia-Brazil gas pipeline (which it calls "the pipeline that benefits no-one"), The Japan-Saudi Jubayl Petrochemical Project, how the sagging Western economy is squeezing Soviet ambitions for Siberian coal development, and the like.

OPEC is defensive about its image in the West. This is seen often, as in, "Campaign Against OPEC," by Gonzalo Plaza, Director General, OPEC News Agency, at a roundtable on international petroleum under auspices of the Centre for OPEC Studies at Caracas on March 22, 1983. In his paper, Plaza opens with, "Since 1973, OPEC has been the target of high-powered and hostile publicity as a cartel of irresponsible Arabs whose actions triggered a severe recession in the industrialized countries and pushed the Third World into an economic crisis, virtually bankrupting the poorest among its members."

He goes on to observe, "The 'cartel' concept is inextricably associated with a collusion of private commercial interests, committed to the maximum of their profits. OPEC is not a trust of private firms and its ultimate objective is to derive from a finite source the maximum possible benefit for the people of its Member Countries, the first and natural obligation of any nation." He contends that OPEC cannot operate as a cartel, which must control both price and production, because each of its members is a sovereign state.

He points out that Article 2 of the OPEC Statute (1980) states:

The principle aim of the Organization shall be the co-ordination and unification of the petroleum policies of Member Countries and the determination of the best means for safeguarding their interests, individually and collectively.

He observes, "Far from being created to manipulate production and prices, OPEC was founded by Iran, Iraq, Kuwait, Saudi Arabia and Venezuela to unify and co-ordinate their petroleum policies vis-a-vis the manoeuvres of transnational oil companies which, acting as a true cartel, by collusion manipulated production, engineered price cuts and blackmailed the producing countries one against the other. (The members of the oil countries' cartel are well known: Exxon, Shell, British Petroleum, Texaco, Gulf, Mobil, Standard Oil of California, and others.)" (The "seven sisters," -Ed.)



He notes that some suggest that the economic downturn stems from, "----a decrease in the rate of industrial productivity in the United States and to the unprecedented budgetary deficits sustained by it since the 1960s."

"In this charged, emotional atmosphere, two powerful groups, representing well-entrenched interests, threw their weight behind the campaign against OPEC: the transnational oil companies and the governments of the consuming countries. For different reasons, both found it expedient and advantageous to make OPEC the scapegoat for their mistakes in order to divert public opinion from their failings. Both made use of their public relations departments and spokesmen to fan the flames of prejudice and slander against OPEC. The companies chose this course in order to hide their role in the rapid and unwise dependence on imported oil induced among western consumers by virtue of prices so unrealistically low that coal and other energy sources were almost wiped out of the market. As for governments - in particular that of the United States - they used OPEC to gloss over their mistakes in the management of their economies."

"It must then, be for the industrialized countries a constant source of irritation to find that a group of Arab, African, Latin American and Asian ministers have turned out to be better politicians, shrewder diplomats and astuter negotiators than the western representatives, presumably more competent. Instead of realizing that the era has passed when political leadership, economic wealth and military power were all concentrated in a few countries of the northern hemisphere, the North opted for the less dignified reaction: insult, slander, scorn and ridicule."

Plaza stresses that OPEC is not an organization of Arab countries, pointing out that, while Algeria, Iraq, Libya, Qatar, Saudi Arabia and the UAR are Arab, the non-Arab states of Ecuador, Gabon, Indonesia, Iran, Nigeria and Venezuela hold 84% of OPEC's population. (He does not mention that the Arab states produce most of OPEC's oil-Ed.)

Views of Saudi Arabia are reported weekly in Saudi Press Agency, "Major News Events," usually summarizing remarks by King Fahd and members of the royal family and the government. This document may be obtained on request from Saudi Press Agency, 1155 15th Street, N.W., Suite 1111, Washington, D.C. 20005.

For example, in the July 25 issue under, "Saudi Press Editorials," it reports from the following Saudi papers:

Al-Medina-Jeddah: Reported King Fahd's efforts to heal differences among Islamic countries. "King Fahd's comments on holy Jerusalem and its miserable fate was designed to remind Muslims all over the world of their religious and moral commitments which they have forgotten for so long."

Al-Jazerah-Riyadh: Condemned the Israeli decision for partial withdrawal in Lebanon as a challenge to the will of the Lebanese people, not conforming to the previous agreement on troop withdrawal signed by Israel, Lebanon and the U.S. (Mentions the U.S. is preoccupied with presidential election campaigns.) Israel is the only power benefiting from new fighting in Lebanon, which is threatening a full civil war, planning for Israel to annex the southern parts of Lebanon.

Al-Riyadh: Commended the PLO Chairman for solving Palestine differences and foiling plots to damage the Organization. Security is threatened not only from abroad, but from internal Arab differences.

Al-Yom-Damman: Deplored U.S. supply of arms to Israel, a double-standard policy. "It went on to say that neither the Americans nor the Russians were interested in realizing peace in the region."

Al-Medina-Jeddah: Reported King Fahd's call to Muslims, worldwide, to return to Islamic fold and "...adhere to the sublime faith."

Okaz-Jeddah: Accused the U.S. of attempting to liquidate the Palestinian struggle by refusing to talk to leaders about their rights. The U.S. agrees with Israel's plans to destroy the PLO and to enforce Israeli conditions on the West Bank. The paper calls on Arab nations to revise their ties with the U.S. because of the wrong foundations of U.S. policy, which will, "----certainly open the door for the Soviets to return as an influential force in the region."

In a statement, "Putting the Record Straight," OPEC Bulletin, July 1983, Dr. Marc S. Nan Nguema, retiring Secretary General of OPEC, expressed many similar thoughts to a briefing of Vienna-based correspondents on June 22, 1983 at the OPEC Secretariat. While he commends some correspondents for objectivity, he commented, "OPEC is news only when it adjusts oil prices. OPEC Conferences are attended by the Western world's media, not to hear about what OPEC Member Countries are doing about co-operation between industrialized and developing countries, about aid to the poorest nations, about health, education and food in developing countries. No: it is one theme and one theme alone that brings the top names in world journalism to OPEC's bi-annual Conferences - oil prices."

Dr. Nguema practically echoed Plaza's remarks about OPEC's not being Arab or responsible for the world economic crisis. "The immediate and crucial factor which compelled OPEC drastically to adjust prices in 1973 and 1974 was the galloping inflation in the industrialized countries, where an economic boom was raising the prices of industrial goods imported by OPEC countries and causing the purchasing power of their oil revenues to decline sharply. The real cause of the 'oil shock' was the failure to allow oil

prices to rise in line with the prices of other commodities. It was that artificially low price which created the dangerous illusion in the West, that crude oil was an inexhaustible resource which could be squandered at will."

Dr. Nguema goes on to contend that OPEC is not wealthy and, while it is also not Arab, he spends some time praising Arab culture and the fact that Arab scholarship preserved arts and sciences while Europe was still in the Dark Ages.

Finally, "Every day the nations of the world are becoming more interdependent, and this is a good thing, for in it lies the future of us all. As journalists, you have a unique role to play in this regard, for you are the opinion-makers. People read and believe what you write. Please try to do justice to OPEC in your reporting; please try to be fair and objective - we ask no more than that."

On the same program and also in the OPEC Bulletin, his talk was followed by an address from Dr. Awni Shakir Al-Ani, Assistant Director of the OPEC Fund for International Development, entitled, "OPEC Aid Goes to Poorer and Less Developed Countries."

#### Other Views on the International Oil Future

Also in the July 1983 issue of the OPEC Bulletin, Dr. Ulf Lantzke, Executive Director of the IEA (International Energy Agency), was quoted as having said the oil market would be, "--- relatively easy over the next three or four years, with eight m b/d spare capacity, which could help economic recovery." But the market will gradually tighten between 1987 to 1990, reaching a "tight" balance, with spare capacity of only two or three m b/d.

In The Oil and Gas Journal, Sept. 12, 1983, "Long Decline in World Oil Output Begins to Level Off," the article points out that world production in the first half of 1983 averaged 51.2 MMBD, off 2.9% from last year. "That's the lowest level in 10 years and 17.2% below the peak first half average of 61.794 million b/d in 1979. Still, it's an improvement from the 8.7% slide between first half 1981 and first half 1982." World production is almost sure to show an increase during the second half of 1983, with slow but steady recovery from the world's recession and reduction in world inventories.

"There is considerable amount of shut in production in countries that are members of the Organization of Petroleum Exporting Countries. As in other years, OPEC had to swallow most of the world's production decline. This year the organization for the first time cut official prices and imposed a 17.5 million b/d production ceiling. (OGJ, Mar. 21, p. 64)." "Non-OPEC production, which has increased steadily for more than a decade, averaged a record 35.4 million b/d during the first half, up 3.9% from last year's first half. That helped reduce OPEC's share of world production to 31.1%, lowest in the organization's history."

"The U.S., with only a 26,000 b/d boost in output, replaced Saudi Arabia as the world's second largest producer. That's because the Saudis cut deeply in an effort to maintain prices and averaged only 4.137 million b/d, off 42% from a year earlier. Saudi output now, however, is increasing. In August, Saudi production averaged about 5.5 million b/d, up 33% from the first half average.---OPEC members may try to recapture more of their lost markets the rest of the year."

"World production has been declining since 1979 due to a surplus of oil that choked international markets. Several factors caused the surplus, but the overriding reason was falling demand brought about by economic recession and price induced conservation. In the U.S., where a mild winter reduced already low consumption levels, oil demand has declined for 5 consecutive years, surpassing the previous sustained drop caused by the Great Depression in 1930-32 (OGJ July 25, p. 114)."

"While some countries shut in production during the year's first half, others substantially boosted output." The biggest increase came in Iran, up 931,000 b/d over first half 1982 and 35,000 b/d over its OPEC quota of 2.4 million b/d. The UK and Norway increased North Sea production, "Canada managed a 167,000 b/d increase by adjusting federal regulations to substantially increase exports and the USSR, the world's biggest producer, increased output by 162,000 b/d." Production also increased in Venezuela, Brazil and Mexico.

"Saudi Arabia experienced the world's biggest production drop--almost 3 million b/d." Other countries with reduced production included Iraq, UAE, Nigeria, Qatar, and Algeria. "OPEC's strategy to halt market losses by cutting prices and imposing production quotas is working."

"In the U.S., the drawdown of stocks has almost ceased."

"Oil consumption by OECD members is expected to rise to 33.3 million b/d in the second half this year from 32.2 million b/d in the first half. And OECD believes total non-Communist demand for oil will rise to 44 million b/d in the second half from 41.3 million b/d in the first half." OECD expects 44.5 and 44.8 million b/d averages for the two halves of 1984.

"Meanwhile, spot market prices have begun an upward trend that has resulted in their commanding a small premium over official prices for many grades of crude." If OECD's forecast is correct, OPEC production could increase to about 19 million b/d in the fourth quarter and 20.3 million b/d next year. While an improvement, it is still far short of over 30 million b/d at OPEC's peak.

"Although it seems unlikely that demand will slump to the level of last spring, markets may require OPEC to reduce quotas or again face a period of surplus." This may require another

difficult OPEC agreement on lowered quotas; during long negotiations, prices could plummet. "Oil demand is the variable that OPEC--and other producers--will be watching very closely."

(A good time to introduce natural gas deregulation in the U.S.--Ed.)

From Exxon News, September, 1983, "In 1983, the demand for oil in the non-Communist world is expected to be about 45 million barrels a day, down only slightly from last year. However, demand should bottom out this year, then turn modestly upward in 1984 as the economic recovery gains momentum." The OPEC crude oil price of \$29 a barrel should continue to hold steady. "The weak demand for natural gas is holding down 1983 production, and it is likely to remain at the company's volume of 5.7 billion cubic feet a day. By the mid-1980s, economic recovery in the U.S. and Europe should lead to an expansion in Exxon's natural gas output."

In a Petroleum Review article, "By 1984 Oil Needs Could Exceed OPEC Quotas," Geoffrey Mayhew interviewed Dr. Herman Franssen, Chief Economist of the International Energy Agency (IEA).

On the importance of the March 1983 OPEC meeting in London, Dr. Franssen comments, "Very significant. The OPEC production agreement of March, and the subsequent action taken by the UK, has had a stabilising effect...It was significant that a formula was found by BNOC (British National Oil Company) that did not undermine OPEC, and it was significant that major oil companies were not going to wreck it...an all-out price war would not have served the ends of any producer. Demand for oil could not pick up to make for losses incurred."

"It (the UK) is not necessarily adverse to lower oil prices, but it is opposed to major shocks which would de-stabilise the market."

"We see an apparent decline in OECD demand of 8 per cent in the first quarter of this year, but---in the fourth quarter of 1983 we expect an increase compared with a year ago.---Consumption will, however, continue to rise, with economic recovery, in 1984...Preliminary guesstimates suggest a two percent increase in 1984."

"The general consensus suggests that by the third quarter the demand for OPEC oil may be just below or just above the March quotas. But the fourth quarter demand for OPEC oil is likely to be substantially above the agreed-upon quotas....it will be much easier to maintain price stability....This would probably continue through the winter of 1983-84. By Spring, 1984, demand for OPEC oil will decline again due to normal seasonal factors but normal OPEC oil demand for 1984 should be well above the 1983 level. One of the principal reasons is that following this year's stock draw there will be very little room for stock draw

in 1984..."

EIA does not speculate on price levels, but Sheikh Yamani is reasonable in assuming that prices will remain unchanged in 1984.

Ever since 1979 oil analysts have over-estimated consumption and under-estimated stock changes and non-OPEC production, consequently over-estimating the demand for OPEC production. "So you cannot blame OPEC for getting it wrong." The duration of the recession has been under-estimated and there have been significant structural changes in industrial demand. "Therefore OPEC was not alone in miscalculating calls on its oil."

"We have gone from a era of over-optimism - the '60s to early 70s - to one of extreme pessimism - the mid '70s to early '80s - and I fear we are now entering again a period of extreme optimism concerning long-term oil market developments. While the current outlook suggests we are likely to have several years of downward pressure on prices, this may not last."

"A great many efforts on conservation may not now take place. The development of alternative sources of energy may now slow down. A good example is the synthetic oil industry which looked so promising in 1981 and the future of which looks dismal indeed. By the early 1990s we could become very vulnerable again to strong upward price pressures due to the resulting supply demand equation."

World Bank: Hobart Rowen in, "20% Oil Price Rise Forecast by Mid-'90s," The Washington Post, July 25, 1983: "The price of oil is expected to rise 20 percent above its 1981 peak by the mid-1990s, with the Organization of Petroleum Exporting Countries' cartel continuing to be the main supplier to consuming nations, according to the World Bank." (Before concluding that the World Bank is out of step with the other forecasts, note that this comment is aimed at the mid-1990s level. It therefore agrees well with the current EIA forecast.)

This author cannot resist commenting, however, that if the EIA forecasts lower price rises for natural gas in NEPP-1984 than in NEPP-1983, the World Bank and other forecasts are likely to be too high on fuel prices.

The World Bank forecast confirms other views that lower oil prices of the past two years have been due to recession and that improved economic activity will demand more oil, "---and a resumption of a strong OPEC influence on the world pricing structure for petroleum." But the Bank expects in mid-1990s Third World, poor countries to regain most of the economic momentum they had developed in the 1960s. Despite conservation, the Bank expects that the "long term dependence" of industrial companies on oil will not diminish substantially. After inflation, the Bank forecast shows a real price increase of 1.6% a year between 1982 and 1995.

Like the EIA and others, the World Bank, "---did not take into account the potential impact of supply increases if the Iran-Iraq war is concluded." OPEC members will remain the main oil exporters because both U.S. and North Sea production should decline.

The Outlook Book-1983, by McDonnell Douglas, forecasts the world economic prospects, including financial outlook and the energy and jet fuel outlooks. In addition, it presents regional analyses for Africa, the Americas, Asia-Pacific, Europe, and the Middle East. It points out that the U.S. fared worse than the world average in 1978-1982, that the recovery had already started here (early 1983), and that it was expected to extend to Europe in late spring or early summer, but remain modest. It is not optimistic for world economic growth in the 1980s, compared to the 1950s, which was substantially lower than for the 1960s. For the world growth rates in the 1960s, 1970s, and 1980s, they give, respectively, 5.2%, 3.6% and 2.8%; and, for the U.S., 3.9%, 3.1% and 2.4%.

The Douglas report includes a fairly thorough account of world and fuel affairs from the 1978-79 oil shock, culminating in the OPEC March 1983 London meeting and reduction of the OPEC marker price to \$29/bbl. But Douglas is doubtful the \$29 price will survive internal OPEC friction, Iran and Iraq war financial requirements, as well as an aggressive Soviet oil export position. Although Douglas notes there are forces working to keep the \$29 intact, they concluded (at the time of the report) that these stabilizing forces are less likely to prevail. Nevertheless, the Douglas crude oil price forecast bottoms out at \$28.92 in 1983, in current dollars, and at \$27.64 in 1985, in constant 1983 dollars, \$2 higher than the EIA forecast of NEPP-1983. Douglas forecasts are shown in Fig.10 for crude prices and in Fig.11 for Jet fuel prices.

In the Texaco Star, No.1, 1983, John K. McKinley, Chairman and CEO, observes that, with world supply and demand in favorable balance, the power of the oil exporting countries has been eroded such that no single country, other than Saudi Arabia, can now cause a world oil crisis. Free world petroleum demand has declined from its peak of 52.0 MMBD in 1979 to 45.3 MMBD in 1982.

In the Chevron Annual Report, "After experiencing some seven decades of steadily increasing demand for energy, the industry entered a new trend in 1981, and will likely be faced by only modest growth in energy consumption throughout the remaining years of this century.---Barring major geopolitical problems in the strategic Middle East, still a large source of the world's crude, we expect oil supplies to exceed demand for some time."

Atlantic Richfield Annual Report: The free World oil demand of 45.5 MMBD in 1982 was 4% below 1981 and about 12.5% below the 1979 peak of 52 MMBD. U.S. oil imports dropped almost 29% in 1982 to 4.2 MMBD, but still are more than a quarter of total U.S.

oil demand. But in the dropping market, ARCO increased production, largely in Alaska; Prudhoe Bay production should continue at about 1.5 MMBD through at least 1987.

The Union Oil Annual Report marks their first year-to-year increase in world-wide crude oil production since 1973. "We estimate that a potential of 600 million additional barrels of crude oil can be produced through the continued use of thermal and tertiary enhanced recovery methods. These potential reserves will be added to the proved category as enhanced recovery projects are implemented."

Marathon Oil Annual Report: "In April, the company sold its Canadian oil, natural gas and mineral interests, ending 34 years of operation in that country. Government policies in Canada had reduced the attractiveness of investment prospects there, and it was evident that Marathon's resources could be utilized more profitably elsewhere."

Standard of Ohio (Amoco) Annual Report: "Our 1982 experience supports our belief that large amounts of hydrocarbons remain to be found in the United States and the rest of the world."

Shell Annual Report (US) concludes that oil prices cannot be predicted.

At Shell Transport and Trading's Annual General Meeting at Shell Centre, London, on May 19, Chairman Sir Peter Baxendell commented, "For the oil business, the agreement among members of OPEC in March of this year on lower official oil prices, on quality differentials, and on production quotas, checked some of the widespread speculation on oil price prospects, and went some way towards creating a climate which has, so far, prevented any further significant decline in spot market prices. We cannot yet tell whether the new price structure will hold: that depends on whether it meets the aspirations of the various OPEC members and whether it has brought the necessary degree of stability to the oil markets."

"It is still impossible to analyse in detail what proportion of the oil demand drop since 1979 has resulted from the economic and industrial malaise of recent years, and how much from a permanent change in consumption patterns. Thus we can only speculate on the potential for demand revival."

Gulf Annual Report states that Gulf is withdrawing from most of its businesses overseas. Like other U.S. companies, it believes large quantities of petroleum reserves remain to be found in the U.S. and that they can be developed successfully and competitively, with greater opportunity and security than abroad.

Exxon Annual Report notes that world pressures to reduce oil consumption come from the recession, conservation, and fuel substitution; growth of GNP is no longer tied directly to energy.



"---Coal demand is expected to grow faster than oil demand over the balance of this century. On the other hand, the outlook for synthetic fuels has radically changed in a year's time because of their greater expected cost and the prospect for ample oil supplies over the next few years." (This may indicate Exxon's immediate view of their interrupted Colony Project-Ed.)

Exxon's pamphlet, How Much Oil and Gas, of May, 1982, points out how much experts have disagreed on the world's oil resource forecasts. "A good example was provided by the 1977 World Energy Conference (WEC), at which twenty-seven petroleum countries, government agencies and individual consultants submitted projections." Noting that the total world history of accumulated oil production is 700 billion barrels, WEC's estimates of remaining available oil ranged from about 3,000 to 7,000 billion barrels oil equivalent. Exxon's statistical chart of these WEC submittals is shown in Fig.12.

"Applying statistical analysis to those experts' views indicates the mean - or most likely - result to be around 4,500 billion barrels. It also shows a 95 percent probability that the resource base was at least 3,000 billion barrels but only a 5 percent probability that it could be as high as 6,500 billion barrels."

Additional perspective on the world's oil and gas production and reserve situations are given by the two charts, Tables 1 and 2, which show the range of the estimated world base and the cumulative oil production by various nations. Table 2 shows that the U.S. has still produced far more oil than any other country in the world, including the USSR. The two charts together indicate that the world still has a long way to go before its presently proved and probable oil and gas resources are exhausted at prices comparable to those today.

Figs.13 and 14 show the rate at which world discoveries have been made and production has been run. Before 1970, new oil discoveries largely in the Middle East, were increasing the world's reserves at some 20 to 30 billion barrels a year. Since production rates were low, these discoveries led to a rapid build-up of oil discovered reserves. After 1970 the situation changed and production surged rapidly ahead of new discoveries. Exxon concludes, "If world oil production holds steady or increases slightly in the years ahead, the decline in the inventory of discovered oil reserves is likely to continue. As a result, oil production eventually will reach a plateau - probably sometime early in the next century - and then begin to drop."

Exxon points out that information about gas is less complete than for oil, but notes, "However, present data indicate that, in contrast to oil, the gas discovery rate still exceeds the gas production rate (Fig.14). Moreover, the world is expected to go on building an inventory of discovered gas reserves, even with projected steady increases in gas production, and is not expected

to begin liquidating that inventory for some years, Therefore, gas production is not likely to reach its peak until well into the 21st century."

### 1983 World Energy Conference

General Programme, 12th Congress of WEC, New Delhi, India, September 18-23, 1983, "Energy Development, Quality of Life," "81 countries from all political creeds at all stages of economic development are now members of the World Energy Conference...At intervals of three years, WEC holds an international congress to which come participants from all over the world. The WEC enjoys consultative status with the United Nations, UNESCO, The Regional Commissions and all specialized Agencies, including the World Bank. It has similar relations with C E M A, European Economic Communities, IEA and other governmental bodies. Their representatives also serve on WEC committees."

"It has working relations with the Organization of Petroleum Exporting Countries (OPEC), and the Organization of Arab Petroleum Exporting Countries (AOPEC) and it has developed unique ties amongst the non-governmental organizations in the energy field..."

This theme of the 12th WEC Congress, "Energy Development, Quality of Life," may carry a significant message; there is apparently less world concern now with fossil energy reserves and even energy prices, than with energy effects on the world's quality of life. In fact, of the 150-odd technical papers presented at the WEC conference, many were concerned with unconventional energy or unconventional uses, with renewable energy, and with the effect of producing energy resources on environment and society. But, unlike previous congresses, there were no papers at all on the world's total supply of energy reserves, methods for increasing oil and coal production, prospects for the future supply/demand balance, or for energy effects on the world economy, not even on the economies of Third World countries.

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- 2-2 Energy Projections to the Year 2010, Department of Energy, Office of Policy, Planning, and Analysis, September, 1983. "A Technical Report in Support of the National Energy Policy Plan Required by Title VIII of the U.S. Department of Energy Organization Act (Public Law 95-91). (In this report, this projection is also often referred to as NEPP).
- 2-3 Kilgore, W. Calvin, "Outlook for World Crude Oil Prices," Remarks at the Energy Information Agency Symposium on

Petroleum Supply Information, Arlington, VA, August 24, 1983.

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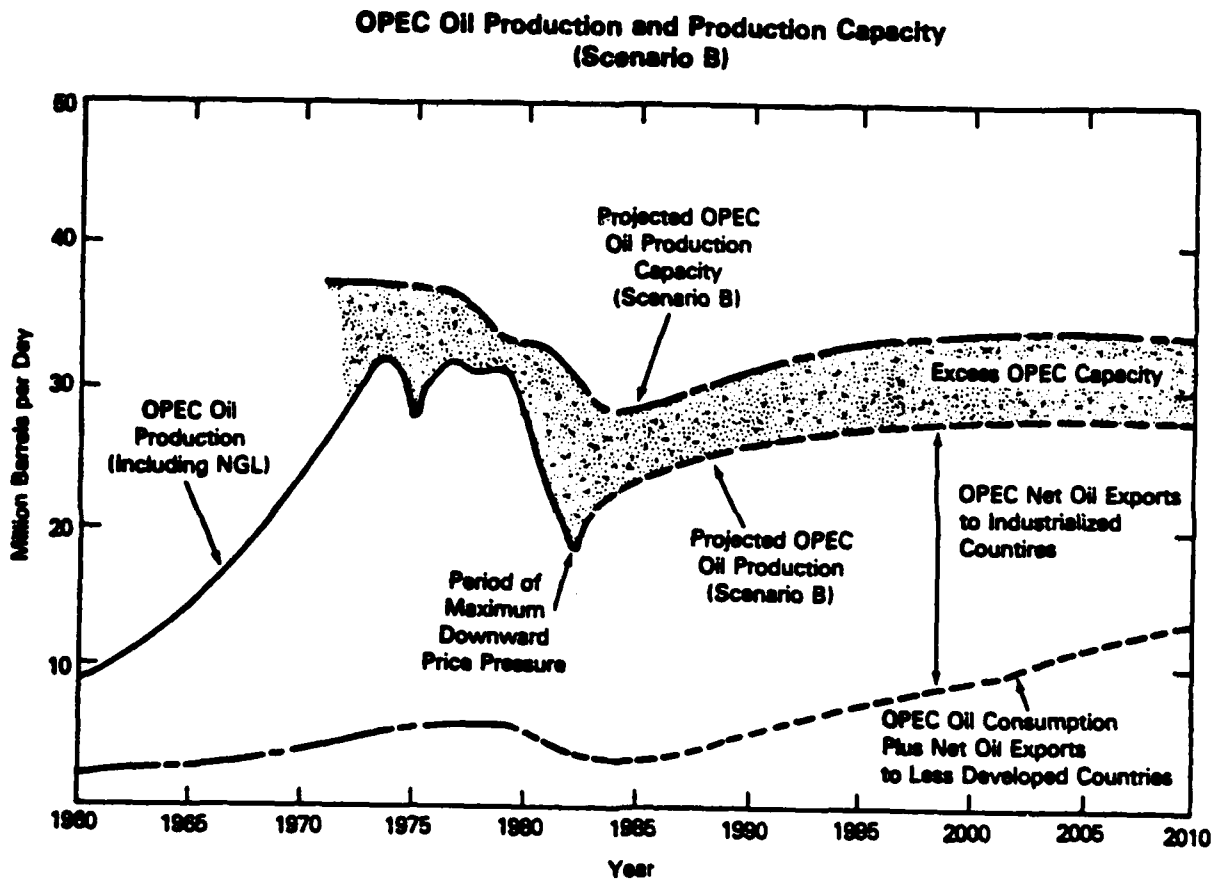


Figure 2-1

## OPEC PRICING BEHAVIOR

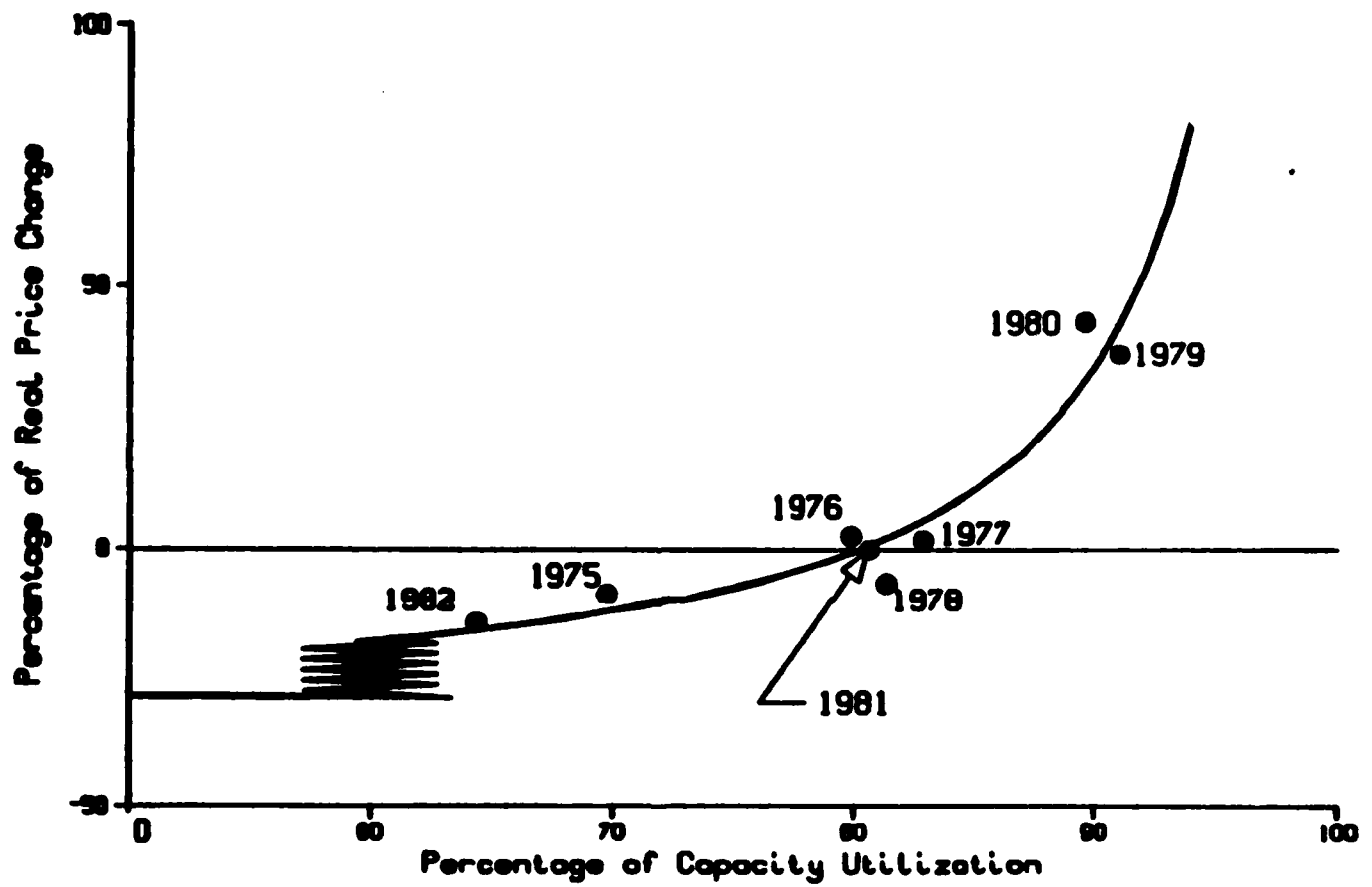
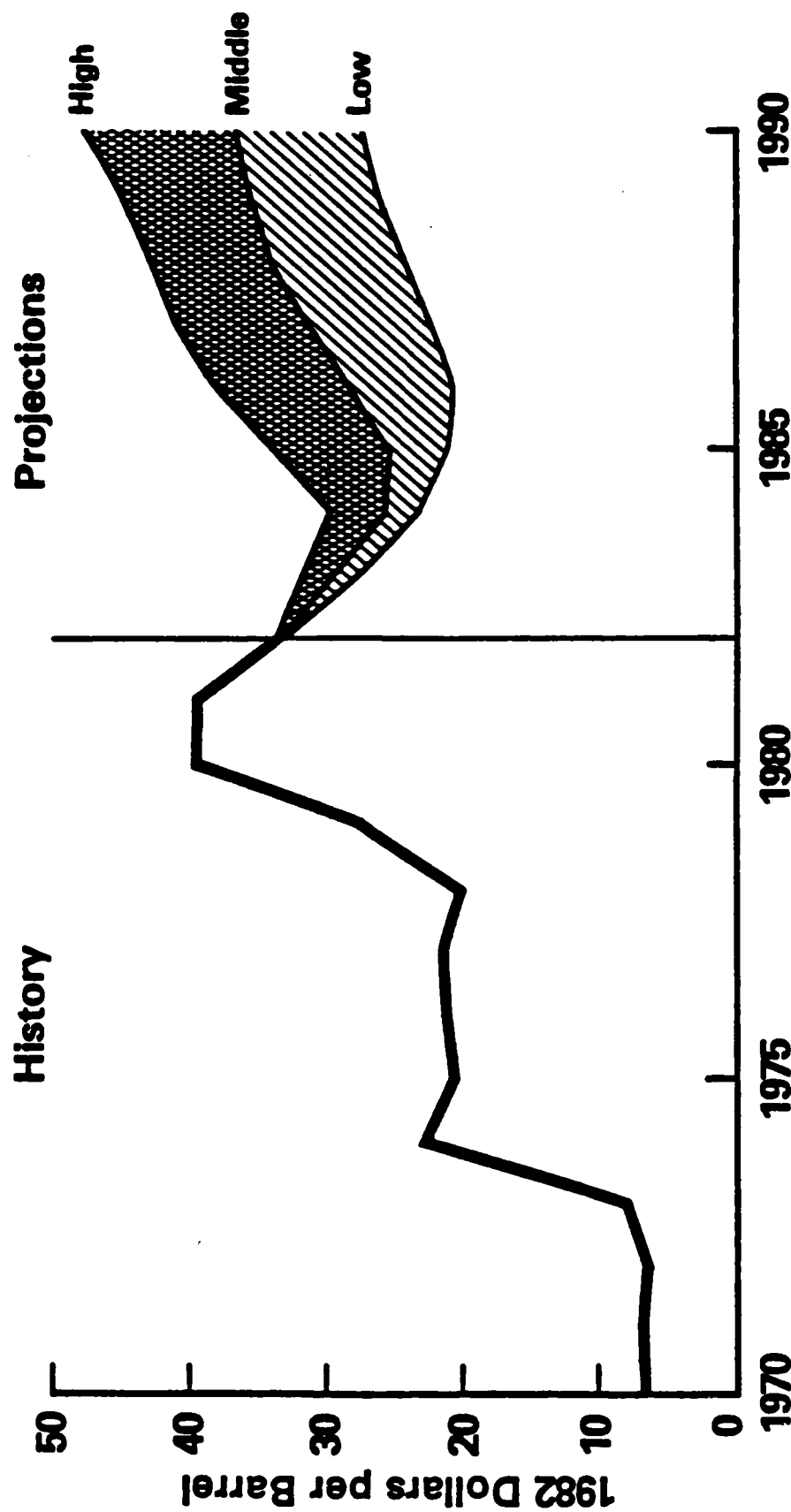


Figure 2-2

# World Oil Price Projections, High, Middle, and Low World Oil Price Scenarios, 1970 to 1990

(1982 Dollars per Barrel)



Note: All prices reflect the average landed price of crude oil in the United States.

Source: Energy Information Administration.

Figure 2-3

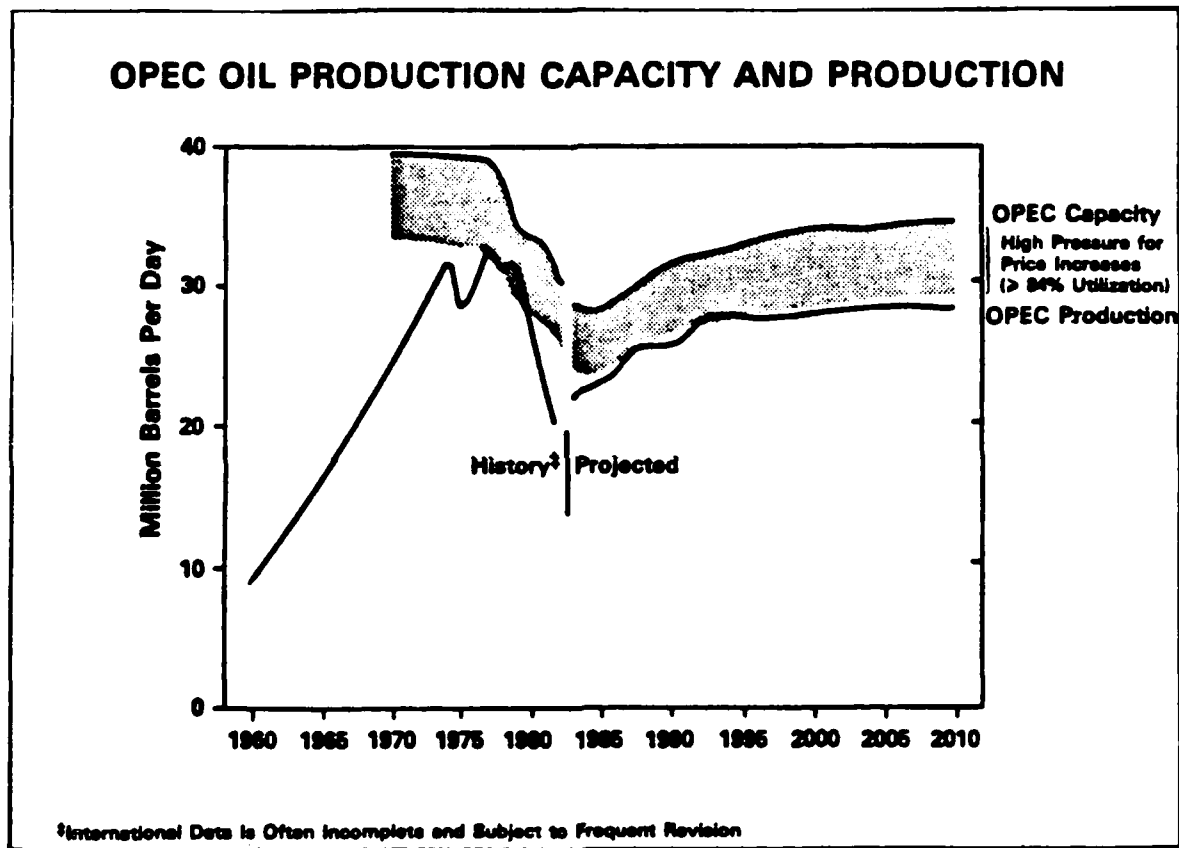


Figure 2-4

### Effect of Alternative World Oil Price Paths on OPEC Revenues 1982-2002

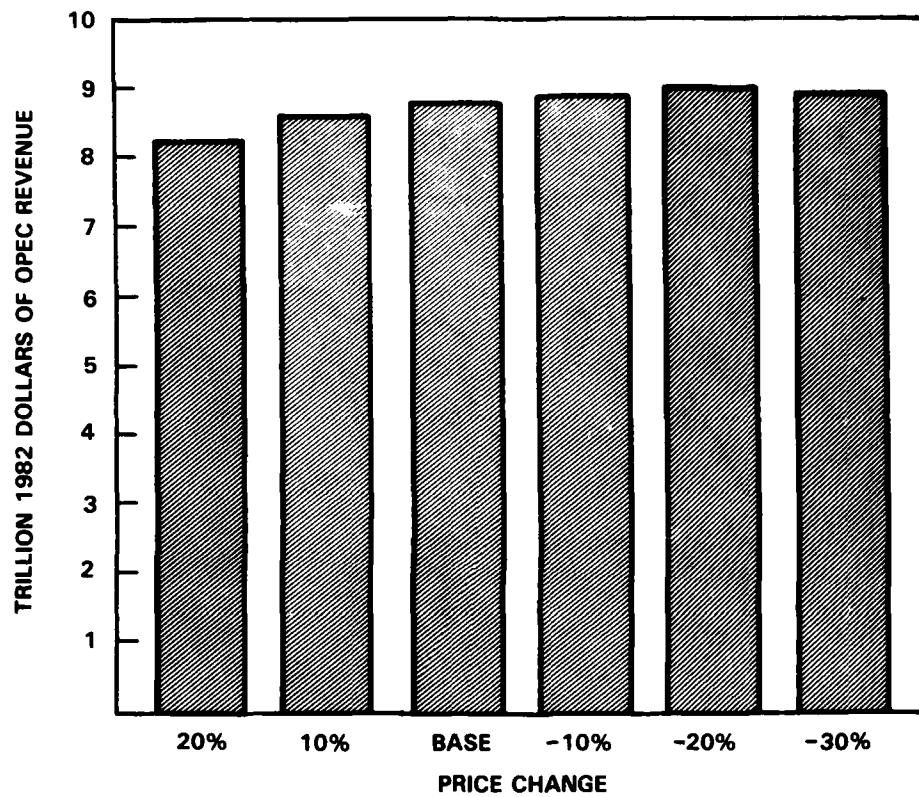


Figure 2-5



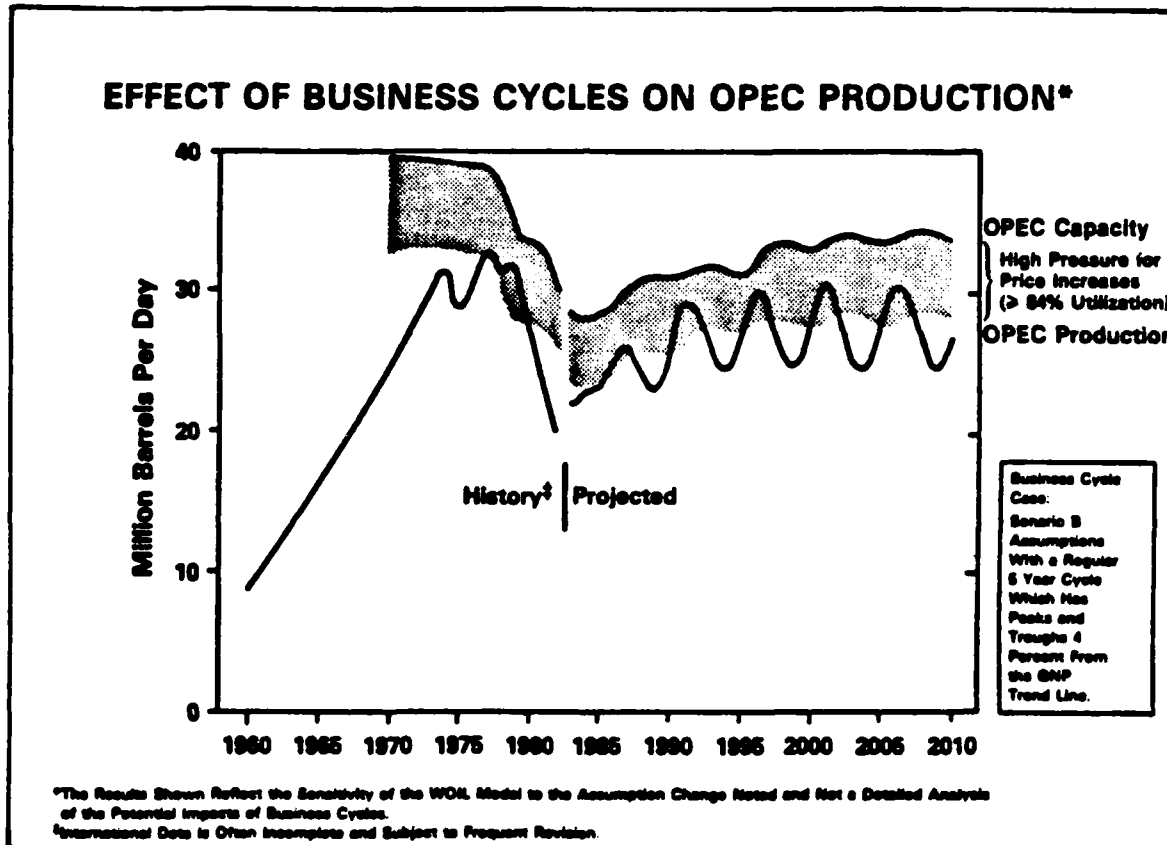


Figure 2-6

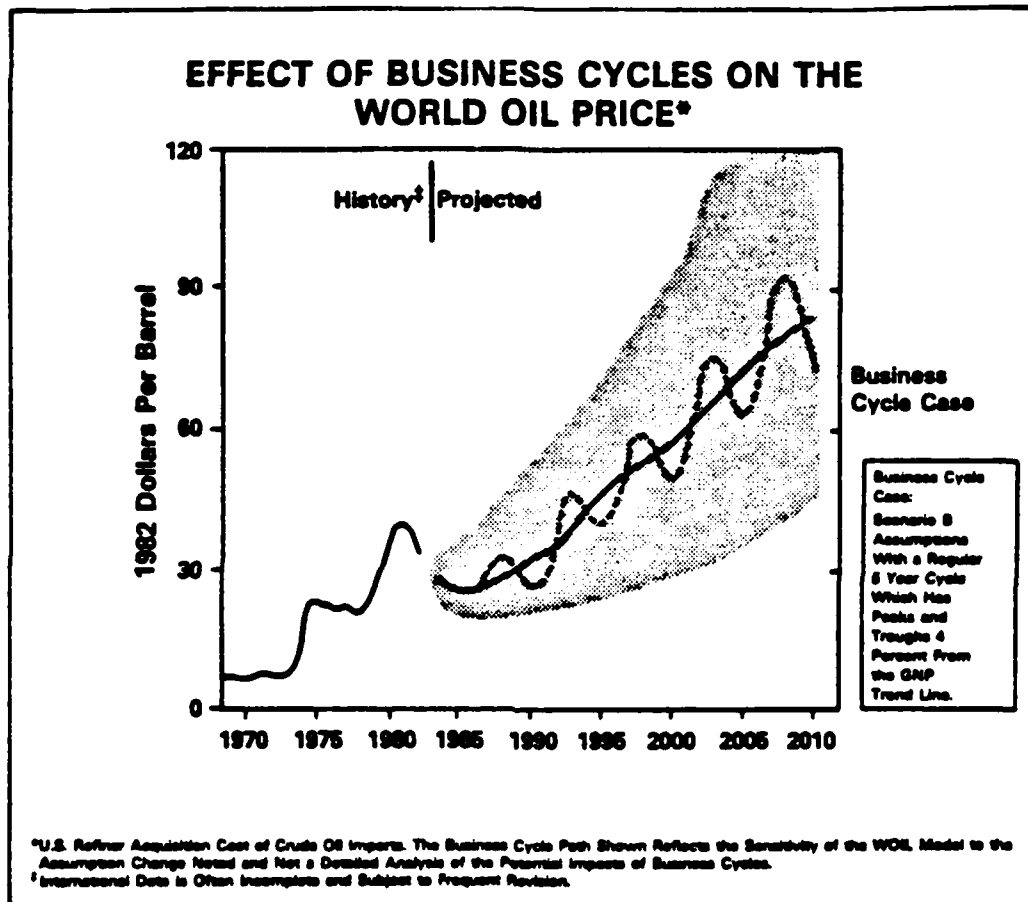


Figure 2-7

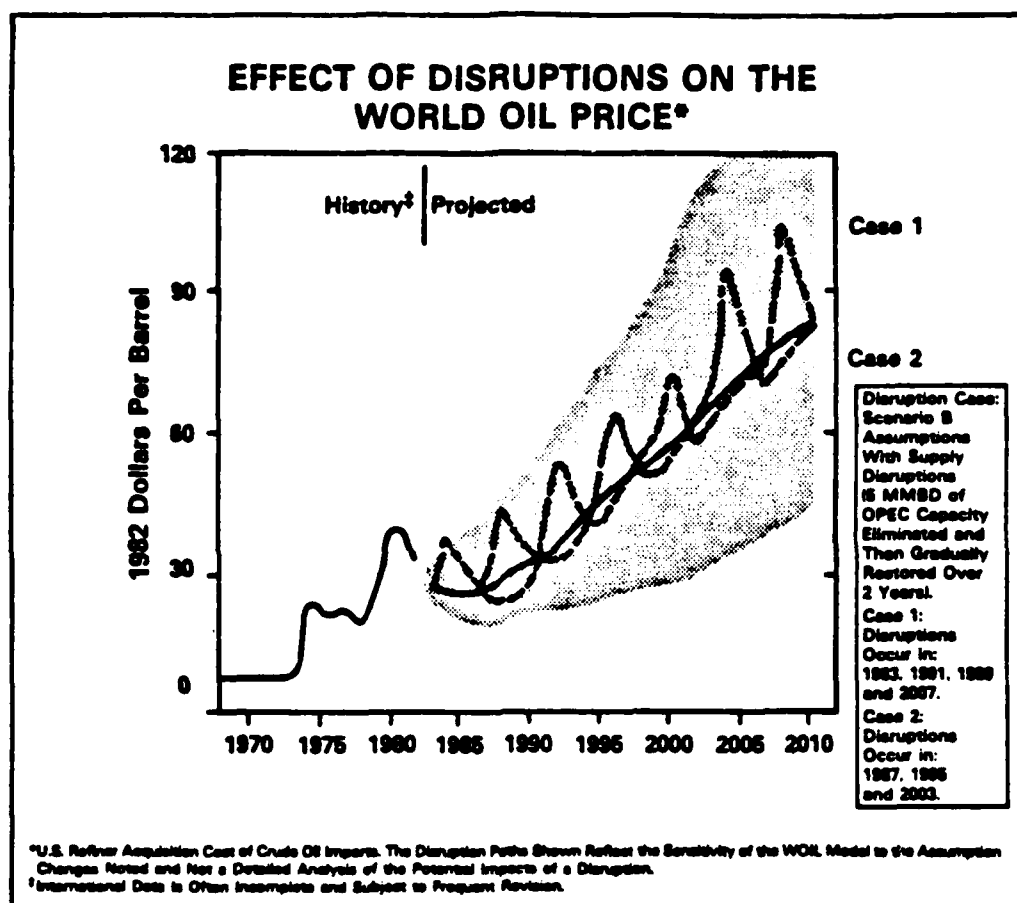


Figure 2-8

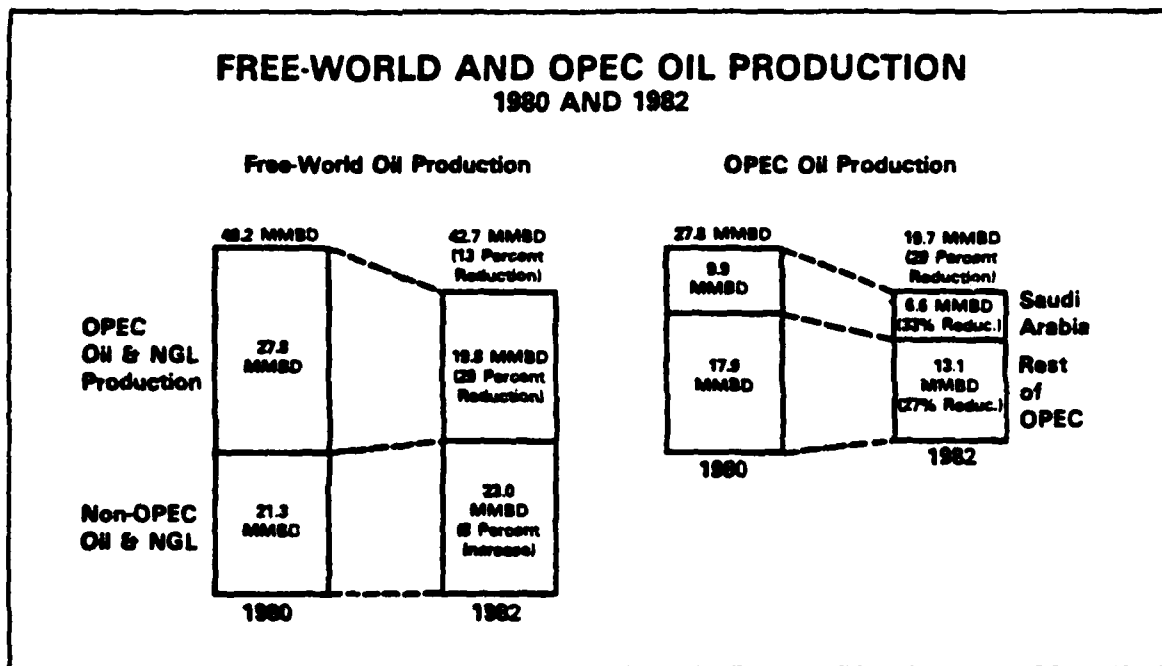


Figure 2-9

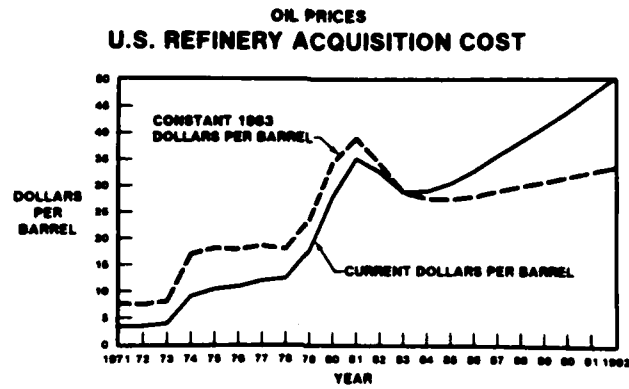


Figure 2-10

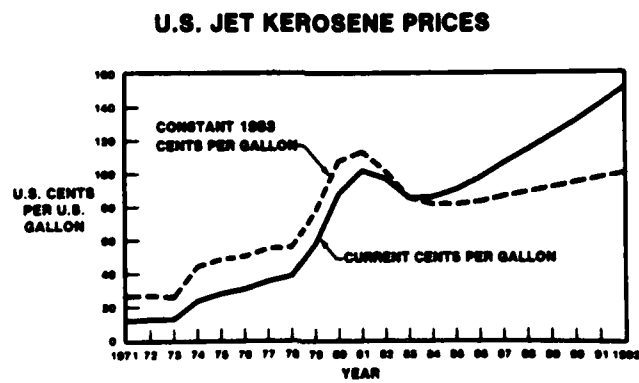


Figure 2-11

# World Total Petroleum Reserves Potential

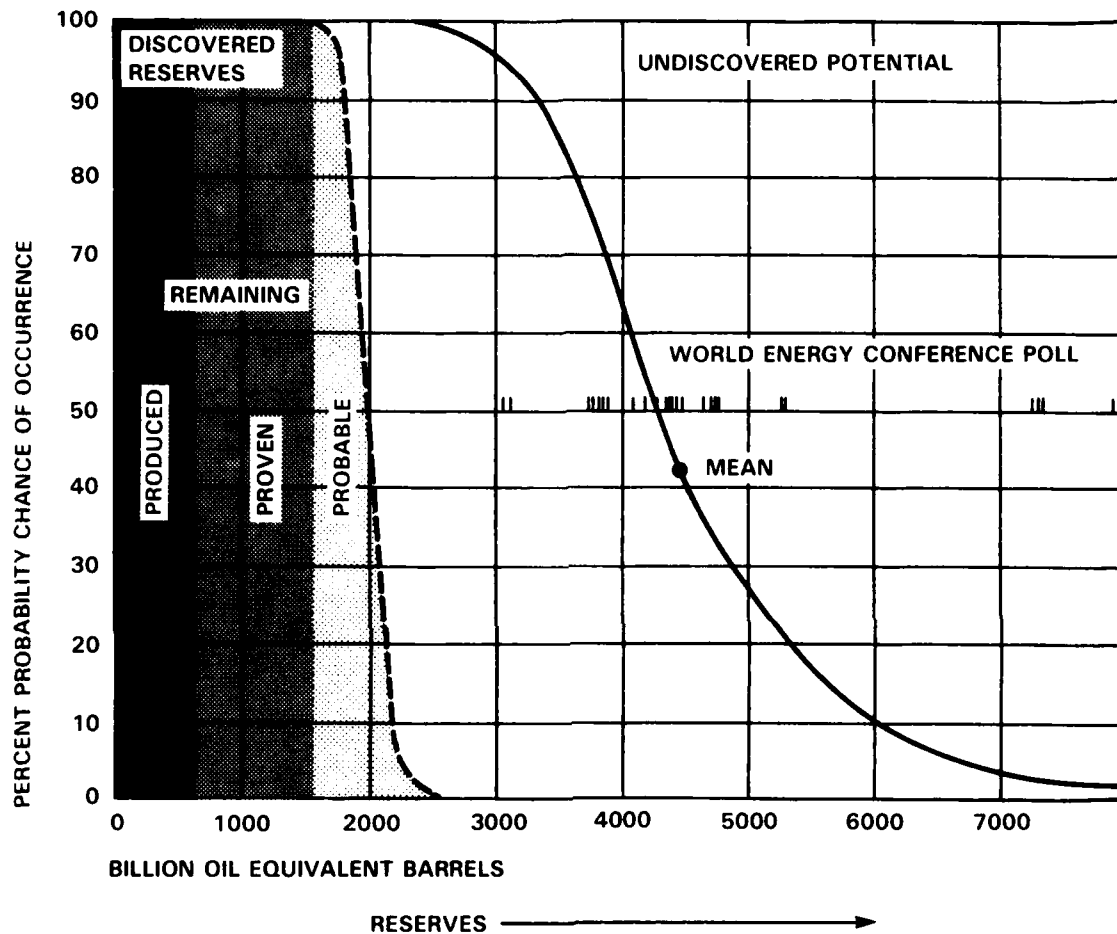


Figure 2-12

Table 1

**World Oil and Gas Resource Base**

(1981)

*Billions of  
Barrels Oil Equivalent\**

Remaining Proved Reserves	1000-1200
Probable Reserves	300-600
Total Remaining Commercial Reserves	<u>1300-1800</u>
Cumulative Production to Date	<u>700</u>
Total Resources Discovered to Date	<u>2000-2500</u>
Undiscovered Potential	<u>1000-2500</u>
Total Oil and Gas Resource Base	<u>3000-5000</u>

*\*Includes crude oil, natural gas expressed as its energy equivalent in oil, and liquids removed from the gas.*

Table 2

**Cumulative Crude Oil Production  
of Leading Countries**

As of July 1, 1981

<i>Country</i>	<i>Cumulative Production (Billions of Barrels)</i>	<i>Year of 1st Recorded Production</i>
U.S.	127	1859
U.S.S.R.	75	1863
Saudi Arabia*	44	1936
Venezuela	36	1917
Iran	30	1913
Kuwait*	22	1946
Iraq	16	1927
Libya	14	1961
Canada	10	1862
Indonesia	9	1893
Nigeria	9	1957
Mexico	8	1901
Abu Dhabi	6	1962
Algeria	6	1914
Argentina	4	1907
Qatar	3	1949

\*Including 50% of Neutral Zone

Sources: Oil & Gas Journal, U.S. Department of Energy



## World Oil Discoveries

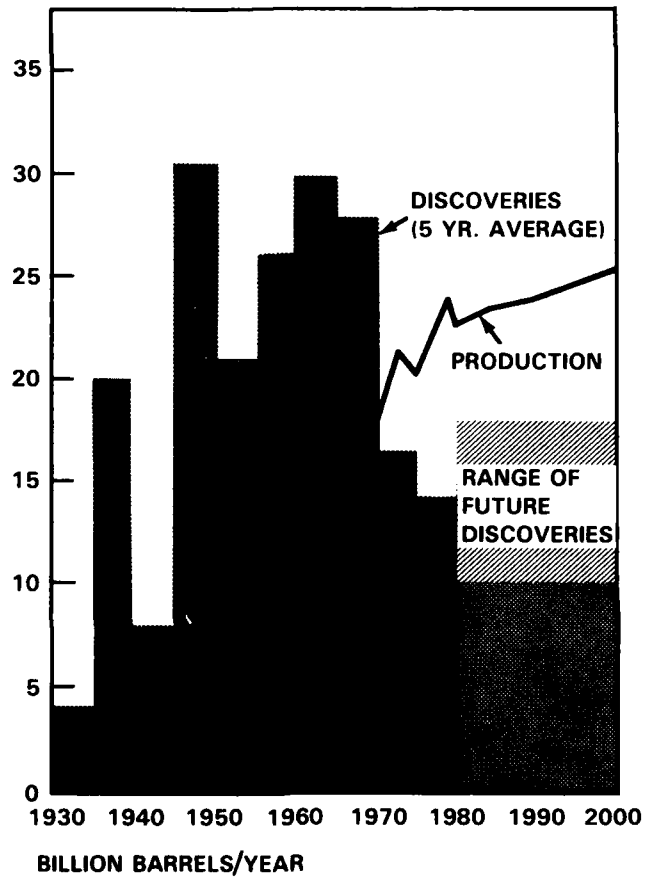


Figure 2-13

# World Gas Discoveries

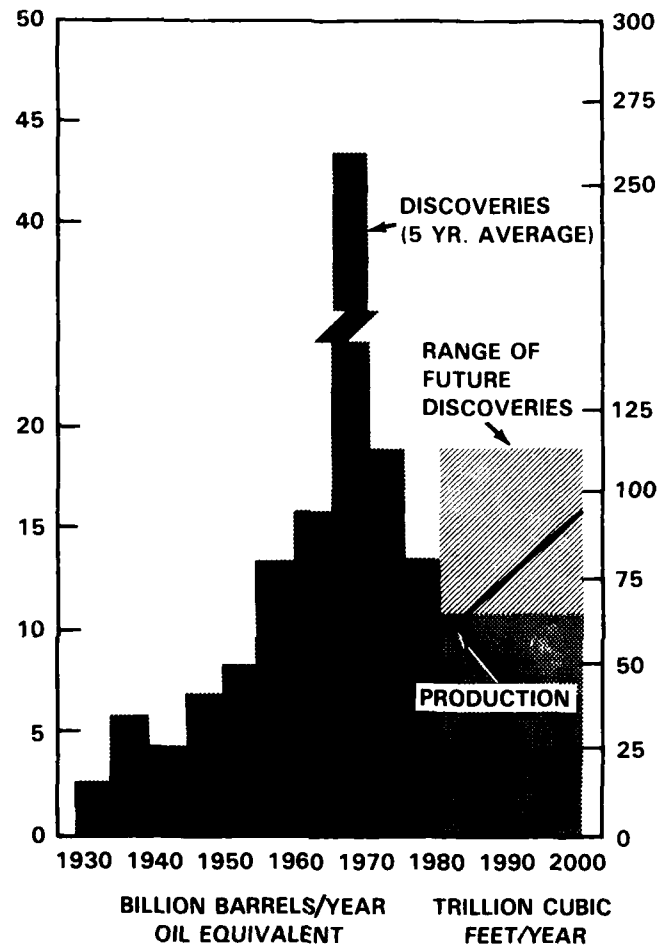


Figure 2-14

CHAPTER 3U.S. EnergyU.S. Total Energy

Before considering future U.S. energy forecasts and implications for aviation fuels, it is well worthwhile for aviation executives to develop some concept of the total U.S. energy picture. If for no other reason, it will lead to an appreciation of how small the aviation component is, and why development in other areas of energy production and consumption can easily eclipse developments in aviation. Aviation may be thought of as a chipmunk amidst a herd of elephants.

This familiarity can be achieved conveniently by examining Fig. 3-1, "U.S. Energy Sources and Uses in 1982," which is taken directly from (2-2), EIA's Energy Projections to the Year 2010. Note that the units used are quadrillion Btus, or Quads.

One Quad of energy is equivalent to about 172 million barrels of oil, or a Quad equals 470,000 barrels of oil per day for a year. A Quad is also equal to about 42 million tons of coal, or 95 billion kilowatt-hours of electricity. More conveniently, 1 Quad equals approximately 1 Tcf, one trillion cubic of natural gas. Or, one Quad equals 503,000 barrels of jet fuel per day for a year, 2,112,600 gallons per day for a year.

Since U.S. domestic civil aviation used just under 10,000 million gallons of fuel for the year 1982, that total annual need is met by only 2.6 Quads of jet fuel.

Looking at the left side of Fig. 3-1, it is seen that total U.S. energy handled for the year was 66.0 Quads of produced domestic energy plus 9.0 Quads of imported oil, 0.3 Quads of oil drawn from stocks, (0.9 imported - 0.3 to stock=) 0.6 Quads of natural gas imported, (plus 0.1 Quads of hydroelectric power from Canada imported into the Northeast but, for convenience, included in domestic hydro), minus 2.8 Quads of coal exported, and 0.6 Quads of coal added to stocks. This nets 73.3 Quads of energy consumed by the U.S. economy in 1982, as shown above the bars.

Of this 73.3 Quads total U.S. annual energy consumption, the 10,000 million gallons (2.6 Quads) of civil aviation fuel amounts to about 3.55%. Of the 30.4 Quads of total oil used by the U.S., 8.5% was used by commercial aviation, up from 6% in 1980, reported in Impact (1-1). As also anticipated in Impact, aviation fuel consumption remained about constant, while U.S. consumption of energy and oil decreased. This drop in total U.S. oil consumption, then, accounts for the aviation "growth" from 6% to 8.5% of U.S. petroleum consumption. Of the 18.6 Quads of oil used by U.S. transportation in 1982, 14% is used by airlines.

While aviation's share of transportation consumption is not shown on the chart, its 2.6 Quad scale is equal to the bar representing the natural gas input to the Commercial Sector, feeding into the second white block toward the right side of the figure. So the width of that bar indicates the size of aviation fuel activity in this picture of total U.S. energy.

Looking further at Fig.3-1, it may be surprising to see that the U.S. is now importing only 9.0 Quads of oil and 0.9 Quads of natural gas, or 13.5% of its total energy. On the other hand, this oil import amounts to 34% of all oil consumed by the U.S. economy, or almost 3.5 times that consumed by commercial aviation. So, although the U.S. now produces a significant percentage of the energy it consumes, the imported oil component is still a significant and important one. (Before assuming complacency over this present U.S. "oil glut", we should reflect that until well after WWII, the U.S. was by far the world's largest exporter of oil and energy.)

It is also worthwhile noting that U.S. energy production is nearly evenly divided among coal, natural gas and oil, with renewables and nuclear sources contributing much smaller shares. Commenting editorially, this shows that if the U.S. increased its natural gas production by 50%, as most analysts suggest is physically feasible before 2000, the nation should thereby be able to discontinue all oil imports. Physically this is entirely possible, but it is prevented by existing regulations, taxes and other institutional barriers.

Also editorially, while enhanced oil recovery (EOR) might increase domestic oil production by as much as 10%, it can be seen in Fig.3-1 that this increase would not be enough to eliminate oil imports. On the other hand, who knows what total U.S. domestic oil production might achieve if, instead of being inhibited by the WPT, local taxes and excises, severance fees, etc., etc., U.S. oil production were encouraged as we presently encourage "renewables"?

When it is considered that "renewables" already includes all hydropower, while present nuclear inputs are relatively so small, from Fig.3-1 it must be concluded that offering attractive incentives for developing renewable energy and removal of all existing obstacles to nuclear, simply cannot achieve a major impact on the U.S. energy picture. If the U.S. wishes to revise its energy import picture and/or wrest the world oil price initiative from CPEC, then this figure indicates where reforms should be more effective. The options must lie in increased production of coal, natural gas, or oil, or in a gigantic synfuel program, which does not appear in the present energy ledger. It appears that a significant increase of domestic energy production could most easily come from natural gas, followed by oil.

Not to be overlooked is the continuing potential for energy conservation. Considering that U.S. energy consumption is down

to 73 Quads from the high of 78 Quads in 1980, this drop of 5 Quads is tantalizing when viewed against our 9 Quads of oil imported in 1982. Unfortunately, the 5-Quad drop resulted largely at a cost of inflation, recession, and unemployment. But reasonable, economical opportunities remain for conservation, and many of them will continue to be pursued because of the high price of energy now, relative to investments made and methods used during the past decade.

Every barrel saved through conservation or increased domestic production is a barrel deleted from imports. The true cost of an imported barrel of oil is controversial and difficult to compute because of many assumptions which must be made. Some economists have estimated costs allocable to the U.S. economy at over \$100 per barrel. The Georgetown Center for Strategic and International Studies shows that this cost is much higher when we include diplomatic and military expenditures made toward securing that imported oil. Costs like \$100/bbl have been used to justify U.S. incentives for "renewable" energy such as geothermal, wind, and solar power, because of consequent reductions in oil imports. Would that we apply the same principles to domestic gas and oil production, where stimulation would have the same effect but, in addition, would depress world oil prices! We should stimulate the elephants more than we do the chipmunks!

It is sobering to consider Transportation's use of fuel in Fig. 3-1, compared to consumption efficiencies in the other sectors, Residential, Commercial and Industrial. Of the 18.6 Quads purchased by Transportation, only 2.2 Quads produced useful work. The remaining 90% went to end-use losses. Of course, much of this loss goes irretrievably to the second law of thermodynamics, and to inefficiency of the Otto cycle in highway vehicles. Nevertheless, the oil lost there is just as real as that which moved the vehicles. It can be seen why some are enthusiastic about the opportunities for future savings, while others propose replacing the Otto cycle with more efficient engines, such as the Stirling cycle.

Some attention should be given to the electrical energy bar, which is shown about top center in the chart, before energy breaks out to its sectorial end users. The picture there is not much better than in Transportation, with over 71% of the energy used lost in producing and transmitting electricity. Again, the second law of thermodynamics contributes. This bar also suggests why economic incentives for co-generation of electric power and process heat (reducing second-law losses) can be so attractive. It also suggests one reason why electrical power is generally not a good prospect for emerging nations. A second, parallel obstacle is the cost of the electrical distribution system. So the world should continue to remain heavily dependent on liquid fuels, particularly the Third World countries.

#### U.S. Energy Prices

From (2-2), Energy Projections to the Year 2010, "Demand for energy in general is presently depressed because of the recession. The market for electricity is expected to recover first, followed by oil and then gas. This phasing will produce interesting relative price patterns. Although coal demand is also expected to increase after a period of stability, huge U.S. coal reserves are expected to keep significant price increases from occurring within the projection period."

Reference (2-2) points out that the past decade in energy has been one of the most eventful in history because:

- o Oil-producing nations took control of assets and prices from the international oil companies.
- o In 1981 domestic oil was deregulated. (It probably should be added that the Windfall Profits Tax, WPT, was also instituted.)
- o With passage of the National Gas Policy Act of 1978 (NGPA), phased decontrol of gas began.
- o The Staggers' Rail Act of 1980 began reduction of ICC control on railroad rates, expecting to raise coal costs.
- o The Three Mile Island nuclear accident is increasing the cost of electricity and costs of new plants.

A revealing picture of U.S. energy prices is seen in Fig.3-2 (2-2), where average prices for electricity, crude oil, natural gas and coal are shown historically from 1960, and are projected out to year 2010. Note that these prices are in constant 1982 dollars. These prices are consistent with the EIA world projection of Chapter 1 and, in fact, show the projected price of natural gas which produces EIA's base price of oil at \$37/bbl in 1990. (Since natural gas contains about a thousand Btus per cubic ft., the prices shown in Fig.3-2 per million Btu also correspond to the price of natural gas per Mcf, which is how gas is quoted and sold on the market.)

In the United States, the 1973 jump of oil prices only slowed consumption growth temporarily. From 1975 to 1978 oil consumption grew at 5% per year, about the same as during 1970 to 1973. Despite a decline from 1973 to 1975, U.S. oil consumption in 1978 was almost 30% higher than in 1970. The second price jump, 1979-80, contributed to the recession and caused significant fuel switching away from oil. Although natural gas remained largely controlled, prices began to edge up in 1974 and have continued to increase under the NGPA. EIA concludes that they will begin to rise rapidly again in 1984 and continue to rise until 1988.

Increases in oil prices contributed to the increased prices shown for electricity in the 1970s. Capital investments were also required to meet the anticipated high growth in demand for electricity. Additional natural gas for electrical generation is prohi-

bited by regulation, so the new generating capacity added was largely for coal and nuclear power. When prices for competitive fuels increased, increased demand for coal permitted higher coal production costs and wages, costs of lower labor productivity, and stricter environmental and safety regulations to be passed along to customers. This was particularly easy with pass-through provisions for electrical utilities.

While coal prices doubled in the late 1970s, they remained low compared to other fuels. Denied its past low-priced competition in electrical generation and much industrial processing, natural gas prices took off when the NGPA permitted high prices for natural gas with high production costs. Most low-cost gas in the U.S. is still regulated at costs far below the market, much at 55 cents per Mcf. And much of it will remain regulated at that level after 1985, when natural gas is supposedly "deregulated". So producers are presently selling their high-priced natural gas, while holding regulated gas in the ground toward future deregulation. One can scarcely blame them, since gas regulated to 55 cents is equivalent to oil priced at \$3.20 per barrel. Natural gas, which had been competing with coal, has now been elevated to a high-priced fuel and EIA predicts it will go relatively higher in the future.

Although electricity is very expensive per Btu compared with other forms of energy, electricity provides unique services, often at a lower cost than other energy forms. Considering Fig.3-1, electricity, as delivered, has already paid for its thermodynamic and transmission losses. For efficient electric motors, electronics and other uses, electricity is a "net" form of energy, compared to gross losses in combustion engines and many industrial devices. (However, by the same token, electricity is a high-priced energy to use for low-grade applications such as space heating.)

As the economic recovery progresses and demand for electricity resumes, more investments must be made in generating equipment. Electricity prices are likely to increase until the late 1990s. At that point, the price of electricity should stabilize. Gas and oil may then account for only 5% of the fuel used in generating electricity. (Note, again, this is an effect of assuming a high price for natural gas-Ed.) Demand for electricity should double over the next 25 to 30 years, influenced by the relatively higher rate of price rises for oil and gas. Since energy resource costs are only 30-40% of the cost of electricity, as compared to over 75% for finished petroleum fuels, the price of electricity is not affected as much by resource price increases as are the other fuels.

As shown in Chapter 2, world oil demand is expected to remain relatively low through the mid 1980s, with no significant oil price increases until the 1990s. This means world oil prices should increase 3-8% in real terms during the early 1990s, then stabilize at about 4% annual growth rate through 2010. Prices of

delivered petroleum products should follow well the trends of crude prices.

EIA now expects that natural gas prices will increase more slowly than in NEPP-1983, so that gas should continue to compete with oil through the 1980s. But the link between gas and oil is expected to weaken in the 1990s and gas prices should remain fairly stable from 1985 through 1995. After 1995, gas prices are projected to increase because of declining domestic production.

(This author observes that these results will occur by continuing our present institutional constraints on natural gas. In a truly free gas market, considerably more gas should be produced at lower prices. But then the whole petroleum forecast and world oil prices would also be changed!)

### Transportation Energy

Still liberally referring to (2-2), about three-quarters of transportation energy is used in cars, trucks, and other road vehicles. The remaining quarter is used in air, rail, and marine transportation, and in powering oil and gas pipelines. The fuel used in pipeline transport is expected to remain fairly stable. (Editorially, if gas pipelines are converted to common carriers from their present private status and gas thereby becomes a fungible commodity in the U.S., gas pipeline traffic could increase considerably, along with the consumption of natural gas. Oil pipeline transport would drop at the same time.)

(2-2) correctly notes that, "Jet fuel demand has also remained stable with efficiency gains balancing increased air traffic. This trend too is expected to continue."

"The use of energy by motor vehicles is not only the largest transportation use, but also the most interesting. Because of improvements in both the design and mechanics of vehicles, it is estimated that the road miles per gallon (as opposed to Environmental Protection Agency estimates) of new vehicles has increased by as much as 85 percent since the early 1970's. This has translated into less than a 2-mile-per-gallon improvement for the entire fleet, however, because of the slow turnover of vehicles. Despite these improvements, it is estimated that only about 20 percent of the Btu's contained in the fuel is actually being used to provide transportation services." Highway fuel and vehicle economy are discussed in more detail in Chapter 4.

"Unlike the other sectors where the expansion of the economy more than compensates for demand reductions, transportation sector total demand actually declines until 1995. At this point, the rate of demand reductions per year slows and transportation energy demand increases."

### Domestic Energy Production (EIA Projections)



"The United States has been endowed with both an abundance and a variety of energy resources. Therefore, historically most of this country's energy needs have been met with domestically produced energy. In fact, United States energy production was over 90 percent of consumption in the 1960's, fell slightly below 80 percent in the 1970's and is estimated to have increased to about 90 percent in 1982. This pattern of relative self sufficiency is expected to continue. In fact, after a brief increase as a result of the economic recovery, U.S. net energy imports are expected to decline throughout the projection period." (2-2)

Note that U.S. net energy imports decline because of increasing coal exports. Oil imports decrease through 1983, but rise sharply through 1985, then decline again, as shown in Fig.3-3.

"Each form of energy has unique characteristics which affect production. Oil and gas production is mostly limited by the volume of proved reserves." (Ed-Traditionally, that is. More recently, oil production responds to market price, while gas production has been restrained by use restrictions and price ceilings on various classifications of gas.) "U.S. coal reserves, on the other hand, are so plentiful that production is primarily limited by domestic and international demand for U.S. coal. Nuclear and renewables are generally capital intensive, with production limited by the technology's cost competitiveness." (2-2)

EIA's predictions for total U.S. domestic energy production are given in Fig.3-4, including oil, gas, coal, nuclear, and renewables. They anticipate a small drop in domestic oil production between 1980 and 1985, holding about steady through 1990, another small drop to 1995, and then steady out through 2010. On average, this amounts to a 1-to-1.5 percent decline per year for the next 10 to 15 years. Based largely on industry actions and commitments, this author is more optimistic than EIA on future domestic production, as discussed later in this chapter.

This EIA forecast shows steadily falling natural gas production throughout the thirty years 1980-2010, decreasing to about 50% of present production by the end of the period. This is an institutional limitation, not a physical or resource limitation. Today, U.S. gas production capacity is considerably higher than demand. Production is limited due to restrictions on the use of gas as well as low price ceilings held on various classifications of gas. Some analysts conclude that present U.S. gas production could be increased 50% by year 2000, based on present reserves and information.

If institutional reform should improve that picture, or if a true free market is permitted, this author contends that considerably more gas will be found than presently identified (and additional gas will be acknowledged which is not inventoried under today's conditions). In the opinion of many, including this author, U.S.

gas production could be increased at least 50% by 2000.

Such a conclusion is not a casual one. It is difficult to visualize the magnitude of U.S. energy consumption. As shown in Fig.3-1, natural gas supplies about one-third of U.S. energy. Although natural gas (methane) is lighter than air and is often used to fill children's balloons, according to the Department of Interior, the U.S. consumes more tonnage of gas than the tonnage of concrete it uses each year. Yes, that is concrete, not just cement; it also includes weight of the sand and gravel used in making concrete.

So an increase of 50% in U.S. natural gas production cannot be taken lightly. In fairness it should be noted that, while many believe production can be increased that much, there are others who think it unlikely. Interested readers may wish to refer to Chapter 6 in Impact.

Based on the history of oil and gas regulation and tax disincentives in this country, and in the absence of any remedial action, this pessimistic EIA forecast of domestic gas production could prevail. But, in NEPP-1984, the EIA expects to show a more favorable outlook for natural gas, both in lower prices, and in higher demand because of less industrial switching from gas to oil.

Referring to Fig.3-5, the present NEPP-1983 forecast for average U.S. natural gas prices (which range from below \$0.30 to above \$9 per million Btu, or per Mcf), gas prices in 1982 dollars are expected to rise from \$2.50/Mcf today to \$5.18 in 1988, then level off beyond 1990. But EIA's unofficial expectation for NEPP-1984, based on existing legislation, is that the price should rise to only \$4.30, as shown. Consequently, there will be less switching from gas to oil, oil consumption in the U.S. will drop and, instead of rising to \$37/bbl (1982) in 1990, the world price of oil will rise to only \$33.

It must be emphasized that this projection is not only unofficial at this time, but that circumstances and analysts' conclusions may change before NEPP-1984 is released in the fourth quarter of 1984.

EIA has estimated the effects of other natural gas legislative scenarios in DOE/EIA-0366, The Natural Gas Market Through 1990, "An Analysis of the Natural Gas Policy Act and Several Alternatives, Part IV," March, 1983. But all of these studies continue the present practices for buying and selling gas, with individual pipeline suppliers maintaining their contracts with individual final distributors.

That is, gas prices retain their wide regional and local variations. In addition to price deregulation and use deregulation, probably more important than price deregulation, pipelines must be given common carrier status in order to dissolve boundaries between private preserves. Until that occurs, or a competitive

national system for distributing liquid natural gas evolves, independent of the pipelines, gas prices will remain at the mercy of the pipelines, just as freight prices were at the mercy of railroads earlier in the nation's transportation history.

Natural gas prices, production, and even reserves are so inextricably bound by legislation and regulation today that further comment is deferred here and the subject is treated more thoroughly in Chapter 6.

Coal is the United States' most abundant fossil resource. Despite its environmental problems, the EIA expects coal to serve strongly in the important energy transition of the next thirty years. Coal-generated electricity will increase until after 2000, when nuclear and renewable sources are assumed to carry more of the burden. Coal production will depend on the dynamics of coal demand, but existing mines and transportation should be able to deliver about 1.0 to 1.2 billion tons of coal per year, which is 175-375 million tons greater than 1982 production. (2-2) Coal producers can deliver this projected 30% increase in production by 1990 with little or no expansion in their present capacity.

EIA notes that some coal reserves could prove uneconomic to mine due to their location under cities or highways, high state severance taxes, or strict environmental laws. However, they conclude that only 50% of the U.S. coal reserve will be able meet the projected demand.

This tremendous supply of coal and the low prices shown in Fig.3-2 suggest other thoughts to this author. With recent developments in fuel-synthesis catalysts and their promising future, one can imagine that the cost of synthesizing liquid fuels, even Jet A, may become competitive within this time period. Since prospects for some of these catalysts indicate that facility costs for synthesis plants may drop significantly, the development cycle time may be shorter than one would otherwise assume.

Further, if synthesis of liquid fuel from gases becomes economically more practical, in situ coal gasification might be used in coal seams which are otherwise too tilted, thin, fractured, layered with rock, or at depths where conventional mining is uneconomic. This technique could not only produce fuel from cheaper coal, but add to the available resource stock of coal. These conjectures are certainly nothing which one should count on. But they are possibilities which may become distinctly possible. While there are few technological developments which now suggest feasible solutions to our U.S. liquid fuel problems, there is always the possibility, even the likelihood, that technology may open some other degrees of freedom which are not now considered feasible and therefore not included in current forecasts.. Further discussion is included in Chapter 7.

EIA's nuclear power projections are based on plant-by-plant analyses which are updated each year. This year's projections are lower than those of the past because of several years without new orders, slowdown in construction, and cancellation of some nuclear plants as much as 30% completed. Much of this action stems from lower demands for electricity than had been projected, financial burdens, and higher construction costs. Much of the higher costs result from increased safety requirements due to the Three Mile Island experience. As demand for electric power resumes during the late 1980s, some new nuclear plant orders may be placed. Nevertheless, a fairly young nuclear authority recently commented on The McNeil-Lehrer Report, PBS, that she does not expect any new U.S. nuclear plants will be started and completed during her lifetime.

For the purpose of the NEPP-1983 projection, EIA assumes existing nuclear policies and programs. If some of the Administration's, or other, nuclear-related proposals to Congress are successful, the EIA midrange projections could be improved. Several commercial fast-breeder reactors could be in operation by 2010, but would not have an appreciable effect on total electricity supply. Beyond 2010, breeder reactors and fusion could become increasingly important to U.S. and world electricity production (if capital costs for fusion are more attractive than for fission-Ed.)

Renewable energy can be used to generate electricity in either central powerplants or directly by end-use customers. EIA considers only power generated in central powerplants; they conclude it is often impossible to determine the conventional fuel which would be replaced locally by renewables. Applications and efficiencies vary too widely. For example, if renewably-generated electricity is used to replace efficient heat-pump heating, the replacement of utility power is about one-for-one. If the renewable replaces electrical resistance heat, then one unit of renewable may replace three units of primary utility power. So the replacement value of renewables is almost always understated (as is conservation of energy-Ed).

Almost all central-electric renewable production in 1982 was from hydroelectric plants. EIA notes that the potential for increasing hydroelectric's contribution is severely limited by availability of sites. They expect the next significant renewable form will be wood, but that it will not penetrate the market greatly. If the prices of oil and gas increase as EIA projects, then large-scale wind, photovoltaic and perhaps solar central-electric technologies will become viable. By 2010, these contributions could equal or exceed hydroelectric production.

As central-renewables are hydro-dominated, dispersed-renewables are dominated by wood use, largely by the pulp/paper industry using waste as a source of process heat. Outside this and related industries, the high costs of harvesting, transporting and processing wood or other biomass energy sources are generally strong constraints to economic use of biomass. Sanitary land-

fills and wastes may contribute small, but important local sources of biomass energy.

EIA concludes that on a national level, significant amounts of solar equipment may be expected after the mid-1980s, with geothermal and then wind playing a role in the 1990s. Photovoltaics are projected to be promising later, producing only 0.05 Quads in the mid 1990s, but increasing to around 0.5 Quads in 2010. These renewables should then dominate dispersed biomass systems just as they dominate hydroelectric in the central plants.

All renewable sources are subject to cost and technical feasibility uncertainties; they are also dependent on the rate of economic growth and on consumer acceptance. "The role of renewables in the national energy equation is, therefore, highly uncertain. Renewables could develop from a modest current contribution to a significant energy supply source by 2010, depending on factors which are difficult or impossible to quantify at this time." Renewables are discussed with other alternative energy sources in Chapter 7.

#### U.S. Domestic Oil (Other than EIA Projections)

EIA's oil production forecast and general outlook, as well as that for natural gas, are conventional and well founded. The majority of oil and gas producers probably agree vehemently with EIA's firm precept: that the rate of oil and gas production at any time is directly dependent upon the amount of proven reserves on hand at that time. It is obviously true that production can only come from reserves which have been proven. Producers also contend that they will never produce more than a given percentage of their proven reserves in any year.

If the price of oil rises, the defenders of this doctrine argue that higher prices will bring out more exploration, development, and identification of reserves. When proven, these reserves go into the pool eligible for production, and production rates may then be increased. This author generally agrees, but not to the exclusion of more immediate economic pressures. If market prices are high, then it is believed that producers are urged by profits and interest rates to increase production and then, using some of that revenue, finance exploration and development to replace the proven reserves which were committed by the increased production.

While a horse usually pulls a cart of hay, there should also be situations in which it can push the cart. If the horse should then eat hay from the cart while pushing, that hay can be replaced from stock in the barn, which he would have eaten when he returned. Or, closer at hand, analysts believed steadfastly for years that any given increase in the nation's GNP had to be accompanied by a proportional increase in energy consumption; the ratio remained inviolably fixed. That was true---until the price of crude oil jumped from under \$3/bbl to over \$30/bbl. Now the

ratio of E/GNP has declined rapidly, and continues to decline in the U.S. and worldwide.

Another example is the MOI, minimum operating inventory which the U.S. must have on hand for processing crude oil to finished products. In recent months, reserves were drawn well below danger points which have long been established and accepted as inviolable. But with higher prices and interest rates expediting action, no shortages developed in products in any part of the country. Now the National Petroleum Council is developing new, lower levels for the MOI.

It does not appear unreasonable to question whether the ratio of production/reserves may have been changed by this same price rise, and by higher interest rates. High interest rates raise the cost of proving reserves in advance of their production. Since the oil exploration-development-production cycle covers over ten years, results are not necessarily apparent as soon as prices rise.

This author believes significant evidence has been seen in trade literature and in oil company annual reports so that, contrary to the EIA declining projection, U.S. domestic oil production has already started to increase and will continue to increase. It may soon exceed the record production level of 1970. And it should not be a short-term phenomenon; proven reserves are expected to increase, backing up the increased production. (But that conclusion is necessarily speculative; proven reserves are only those which already have been proven.)

Some company annual report comments which may be pertinent to future U.S. domestic oil reserves and production:

It is now much less expensive to drill wells in the U.S. than in 1981-82; companies report costs have dropped by 1/3 to 1/2 in some cases; there is a surplus of drilling rigs. While most companies report 1982 exploration and development investments are down from 1981, they are still above 1980 and the number of successful wells has increased.

The Santa Maria Basin off-shore California is the largest domestic find since Prudhoe Bay. It has been confirmed as a giant field, 300 to 500 million barrels. Some believe that the Bering Sea promises finds as bright as or exceeding the North Slope. While the Baltimore Canyon has been disappointing in oil to date, it offers much gas promise; farther from shore and southward appears promising. Deeper horizons are looking good in on-shore fields, while EOR may finally blossom with carbon dioxide piped to Texas from Colorado, and newer CO<sub>2</sub> finds near and in the oil fields.

One company reports, "We estimate that a potential of 600 million additional barrels of crude oil can be produced through the continued use of thermal and tertiary enhanced oil recovery methods.

These potential reserves will be added to the proved category as enhanced recovery projects are implemented." Several companies advise that for the first time since the 1970s or 1960s, their domestic proved reserve additions have exceeded annual production. One company comments, "Our 1982 experience supports our belief that large amounts of hydrocarbons remain to be found in the United States and the rest of the world." (Admittedly, however, many of these promises must pan out to offset declining output from producing wells; Prudhoe Bay is expected to begin production decline in the latter half of the 1990s.)

Several companies increased their domestic proven reserves over 1981 and some have set goals to continuously increase domestic reserves through this century, while at the same time increasing domestic production. One company replaced 3.5 times the gas it produced during 1982. (Even though gas is not a very attractive commodity-Ed.) Other companies have decreased or suspended foreign resource development in favor of increasing domestic operations. (When foreign oil was cheap, U.S. producers typically moved their efforts abroad; since the large increases in OPEC prices, domestic sources are comparatively more attractive again. By the same token, much U.S. activity has pulled out of Canada because of unfavorable Canadian regulations and taxes.-Ed)

"Our best estimates at Shell indicate that - given sufficient funds and access to the most promising areas - the industry has at least a 50-50 chance of finding oil and gas equal to twice the existing U.S. reserves." Others report that large quantities of petroleum reserves remain to be found in the United States; the atmosphere is remarkably different than that three to five years ago.

But finally, in fairness, the American Petroleum Institute annual forecast was reported in The Oil and Gas Journal, September 19, 1983: "API: Don't be Complacent About Oil Supply." It warns that the U.S. is in danger of slipping back towards its dangerous position of the 1960s. While noting that the U.S. has made much progress, by the end of the century more than 75% of U.S. domestic oil must come from fields that have not yet been found. As seen in Fig.3-6, taken from the OGJ, API shows not only the magnitude of this task but that, even with its accomplishment, U.S. oil production is still predicted to decline steadily from today until 1995. This author has the temerity to believe otherwise.

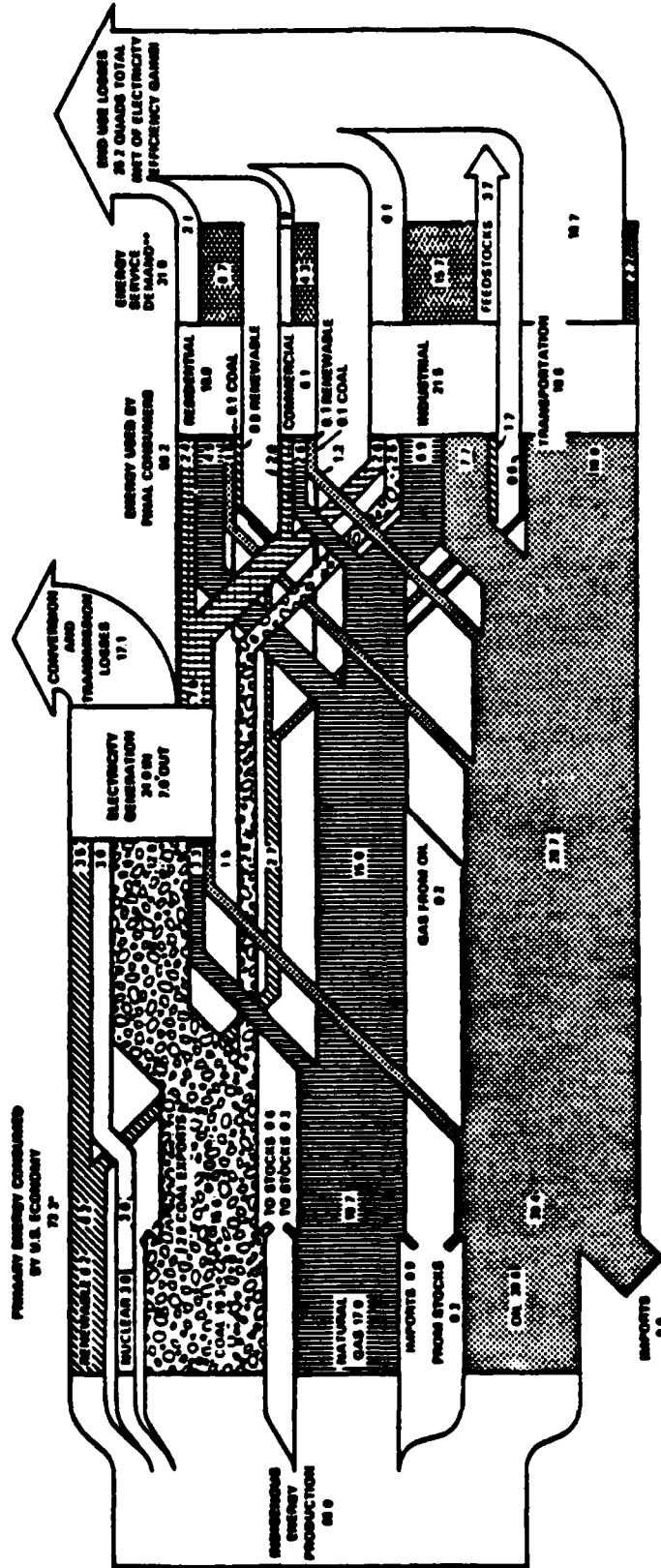
#### The National Energy Policy Plan (NEPP-1983)

Having reviewed U.S. energy demand, supply and pricing prospects for the future, it could be appropriate here to review the policy and tactics highlights of NEPP-1983, which is a report to the Congress by the U.S. Department of Energy, required by Title VIII of the Department of Energy Organization Act (Public Law 95-91). However, that plan can be stated very briefly: The Government intends to let free market forces determine energy activities in the United States.

More detailed elements of NEPP-1983 should be considered in the context of energy disruptions, emergencies and use of the Strategic Petroleum Reserve. The review of NEPP-1983 is therefore located at the end of Chapter 9.



# **U.S. ENERGY SOURCES AND USES IN 1982** (IN QUADRILLIONS OF BTU)



\* INCLUDES 0.1 QUADRILLIONS OF IMPORTED HYDROELECTRIC POWER  
 \*\* INCLUDES 3.7 QUADRILLIONS OF ENERGY RESOURCES USED AS FEEDSTOCKS FOR THE MANUFACTURE OF NON-ENERGY MATERIALS BASED ON END USE EFFICIENCIES FROM 1980 BROOKHAVEN DATA

Figure 3-1

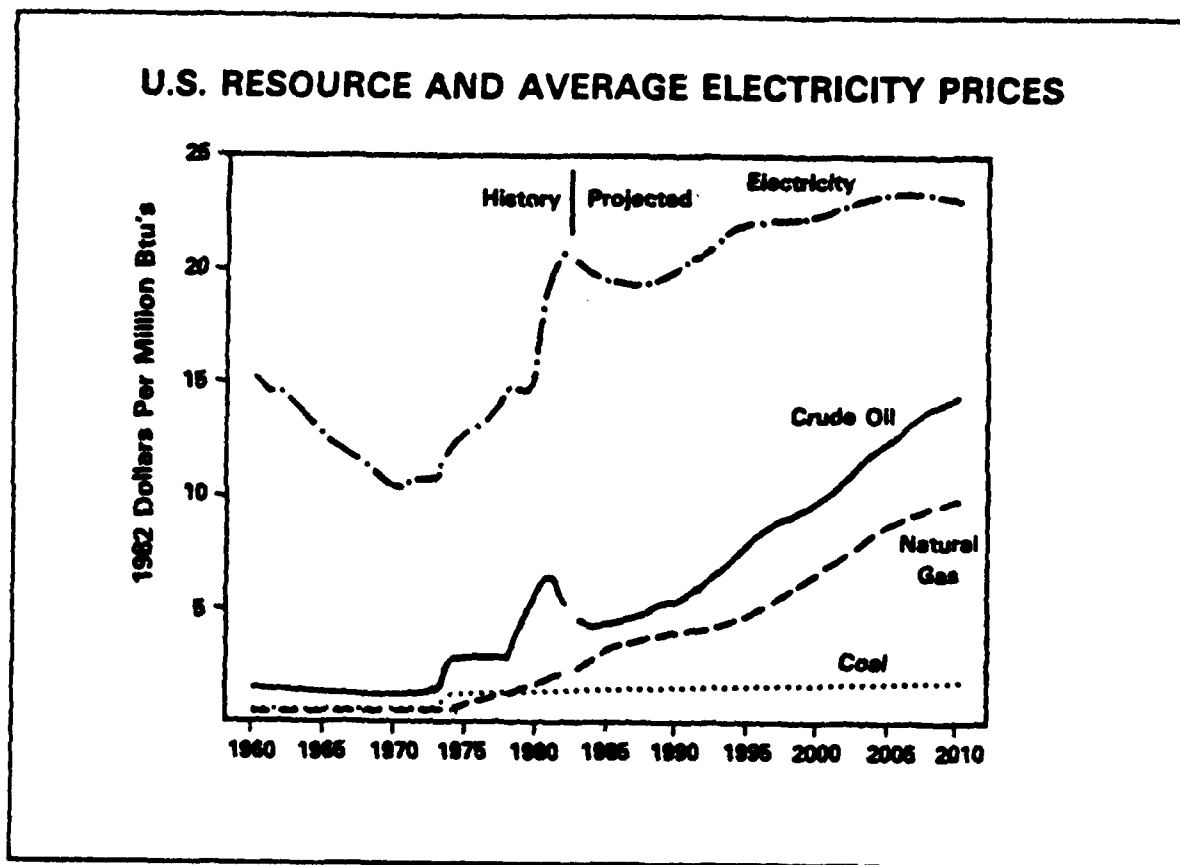
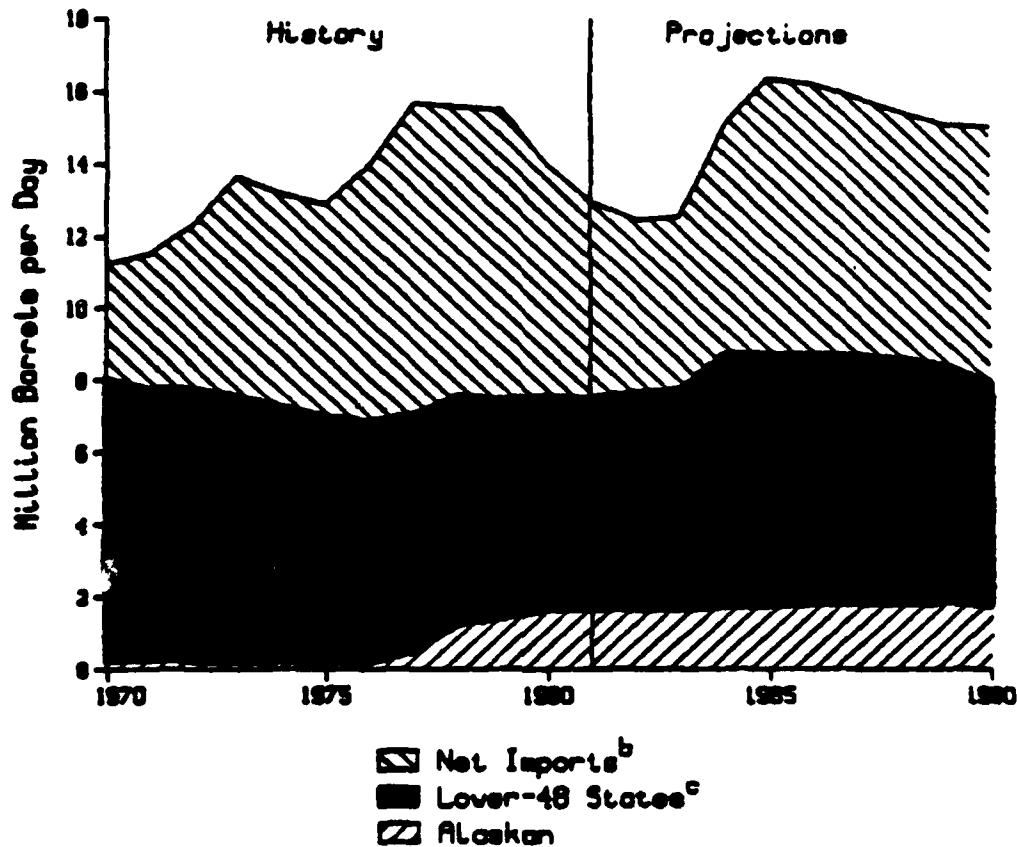


Figure 3-2

U.S. Oil Supplies By Source<sup>a</sup>,  
Midprice Scenario, 1970 to 1990  
(Million Barrels per Day)



<sup>a</sup>Excludes domestic production of natural gas plant liquids.

<sup>b</sup>Includes imports for the Strategic Petroleum Reserve.

<sup>c</sup>Includes offshore production.

Figure 3-3

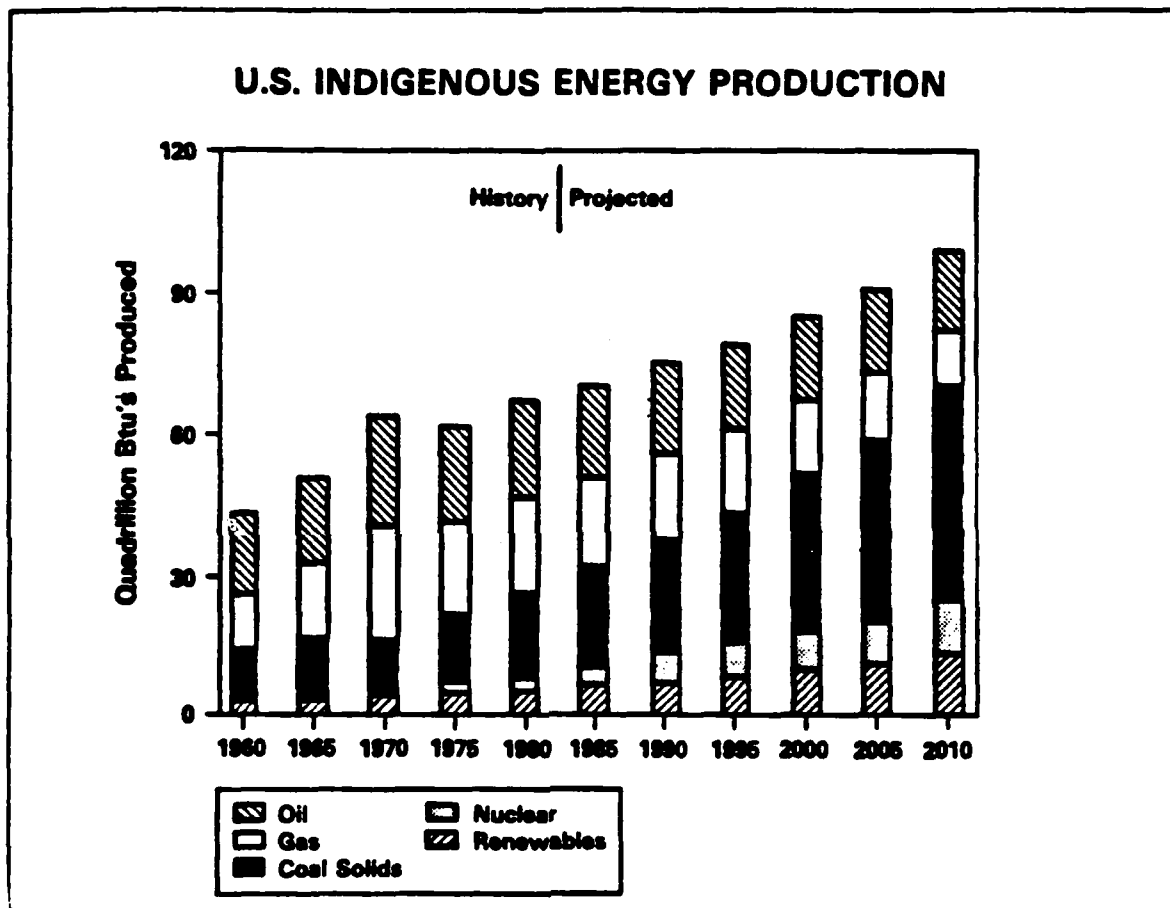


Figure 3-4

***U.S. Average Wellhead Price of Natural  
Gas, Midprice Scenario, 1980 to 1990  
(1982 Dollars per Million Btu)***

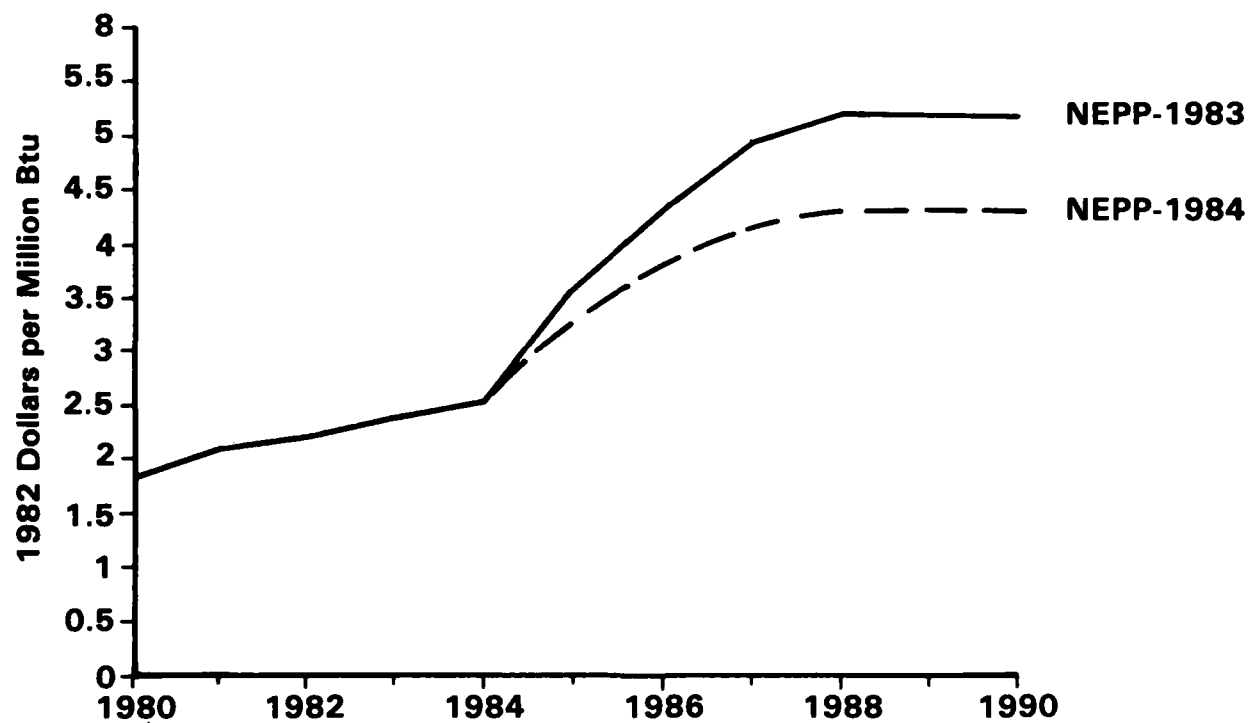
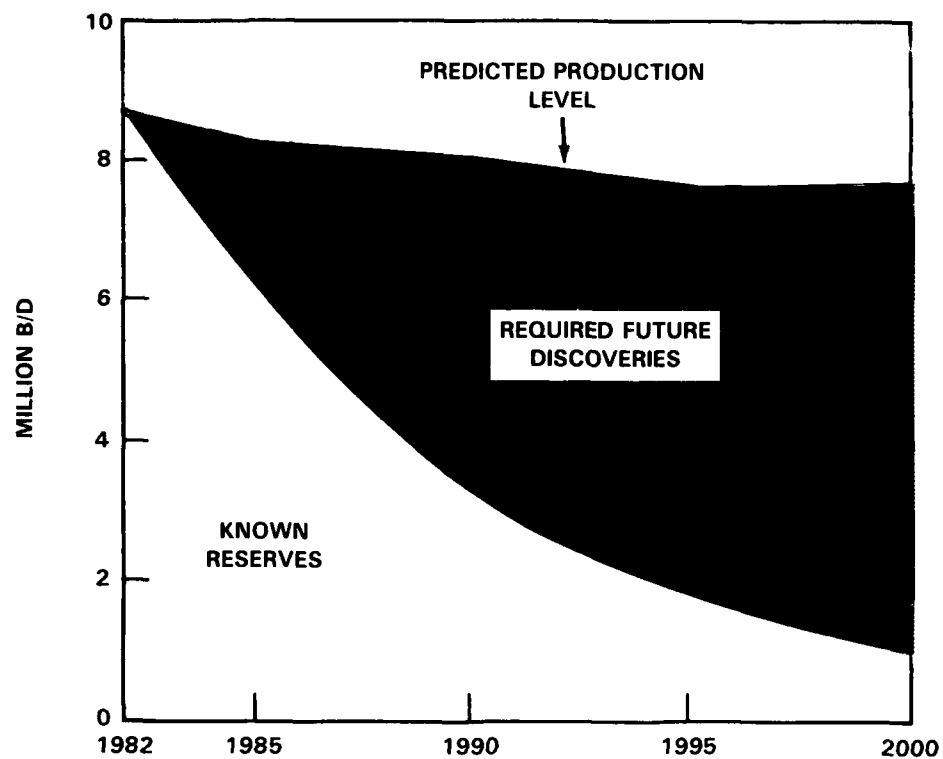


Figure 3-5

## The Outlook for U.S. Oil Production



SOURCE: AMERICAN PETROLEUM INSTITUTE FROM DEPARTMENT OF ENERGY DATA

Figure 3-6

## Chapter 4

### U.S. Automotive Fuel

As shown earlier, automotive vehicles consume about three-quarters of transportation fuel used in the United States. Consequently, developments or events involving automotive fuel usage are likely to affect aviation fuel supplies, prices and destinies more than many major events in the aviation arena. It is therefore appropriate to outline here the main features of automotive fuels in the U.S., as well as projections for their future.

Much of the information here is taken directly from an excellent, comprehensive report by David L. Greene, Transportation Energy Group, Oak Ridge National Laboratory, DOE, which was presented at the Energy Information Administration Petroleum Supply Information Symposium in Arlington, VA, August 24, 1983. For simplicity, only other sources will be referenced, so the reader may conclude that all unreferenced charts and information come from that source. In fact, this account is essentially a digest of Greene's report; this author does not differ with his information or conclusions in any respect, and selects it in preference to other highway analyses or reports on the subject.

Again, like the previous EIA material presented on world and U.S. energy, this picture of the automotive fuel market is consistent among its own components, as well as with the earlier world and national pictures. It is the source for automotive inputs into NEPP-1983.

As indicated by Fig.4-1, U.S. automotive vehicles consumed 100 trillion gallons of gasoline and 15 trillion gallons of diesel fuel in 1981. Other fuels, such as ethanol, methanol, LPG, CNG and LNG were used in such small quantities that they do not register on this scale. They are discussed in Chapter 7.

Fig.4-1 also shows that gasoline consumption reacted somewhat to the 1973-74 crude oil price rise in Fig.4-2 (Impact), but resumed its climb, virtually unabated, until the second price shock of 1979-80. At that point, gasoline consumption began a steady decline at about the same rate with which it had so recently grown. The gasoline consumed in 1982 was slightly lower than that of 1973.

By contrast, highway use of diesel responded very little to either price rise and its consumption growth has continued at almost a constant rate. By 1981, diesel consumption was 50% greater than in 1973. Diesel fuel consumption therefore seems to be less sensitive to fuel prices than is gasoline, for reasons which will become apparent. As also will be seen, the extent of future fuel switching from gasoline to diesel fuel in automobiles and light trucks is the most important factor in

determining future diesel trends. In turn, this outlook is one of the most important considerations for aviation because of the close relationship between diesel fuel and Jet A; they both compete for the same fraction of the crude barrel.

Rather than keep aviation readers in suspense, it will be said here at once that, perhaps surprisingly, it is not expected that dieselization of U.S. light trucks and automobiles will continue to grow in the future; future growth of diesel consumption is expected to grow essentially at the same rate as the GNP and to present no unique threat to future aviation fuel. The reasons for this conclusion will be fully illustrated. As in all other forecasts, particularly those concerning energy and fuel, this conclusion is subject to all the caveats which have already been expressed. But, if world and national economic, political and social trends continue as assumed, this conclusion is an unusually firm one.

### Past Trends

About two-thirds of energy used for all types of transportation in the U.S. is from gasoline and almost all of that (97.5%) is used on the highway. Since now, as will be seen in more detail later, nearly all heavy highway equipment is diesel-powered, gasoline trends may be developed from trends in automobiles and light trucks together. They account for more than 90% of total gasoline used.

For perspective, in 1981 U.S. domestic aviation used 538 million gallons of gasoline, or about only 0.35% of that used by automotive vehicles. Jet fuel, at nearly 10 billion gallons in 1981, was about 8.7% of the fuel used by automotive vehicles. As seen in Fig.4-3 (2-4), jet consumption is about 80% the amount of diesel fuel consumption. In this chart, both jet fuel and diesel grow very little from 1983 to 1990, while retaining about their same relationship. However, since gasoline demand is expected to decline 20-25% in the same period, both jet fuel and diesel will become larger percentages of the national transportation fuel used.

From 1950 through 1973 U.S. gasoline use grew at an average rate of 4.7%. It had declined only twice in U.S. history; during the Great Depression and again during WWII. But, since the great crude oil price rise of 1979, Fig.4-2, gasoline use has declined for four straight years, the longest downturn on record. (Gasoline consumption is expected to decline on out for the rest of the century.)

Not all of this decline has been due to the high price rise. "Government fuel economy standards, a weak economy, and dieselization have all played important, interrelated roles." But price has been the pervading, underlying force behind this trend.



While gasoline was 35 cents/gal in 1970, we tend to forget that was about 90 cents in 1982 dollars. From Fig.4-4 it can be seen that the real price of gasoline today is still only about 140% of its real price in 1970.

As gasoline prices were fluctuating in Fig.4-4, beginning in 1975, new car fuel economy began a steady climb, as shown in Fig.4-5, so that the cost of fuel per mile was affected as shown in Fig.4-6. So, for new car drivers, fuel cost/mile peaked in 1974 and shows no signs of returning to that level. It is now the cheapest on record, about 4.4 cents/mile and almost 30% below 1969 levels. All this fuel-consumption information is based on EPA combined fuel economy for new cars. Since on-road experience has generally been 10-20% worse, all these figures should be adjusted by that amount, but the relationships remain. The cost of fuel in new cars is very low today, relative to any point in history.

As seen, the story is somewhat different for the total vehicle fleet, where the highest cost peaked in 1980, not 1974. Since then the fleet cost has dropped from about 9 cents/mile to 7.7 cents/mile. This is still not much above the 1969 level of about 6.8 cents/mile. Even though stock turnover is relatively slow, the newer cars continue to have better fuel economy and the real price of gasoline is continuing to drop. The fleet average cost for fuel therefore should soon drop below that for 1970.

"In the short run, consumers respond to higher fuel prices by cutting back on vehicle usage." Although seasonal trends tend to swamp non-seasonal trends, this influence was confirmed in 1979 and 1980, when the price of gasoline rose by 50%. Interestingly, an econometric study showed that the use of vehicles of different sizes responds differently to changes in gasoline price. Use of small cars drops only half as much as for large cars, while light trucks fall about midway between the two. Total vehicle miles grew at about 4% per year until 1979, but has held about constant since that time. The decrease in total gasoline demand since 1979 is therefore attributable to better fuel economy in the fleet.

"Since 1979 lagging sales and reduced scrappage have retarded stock efficiency improvement...Had 1979 rates of sales and scrappage prevailed in 1982, the change in vehicle stock fuel economy might have been 30% greater than it was."

Fuel economy of new cars had been slowly but steadily declining until 1974, when gasoline prices abruptly rose by 35%. Congress passed the Energy Policy and Conservation Act of 1975, establishing Corporate Average Fuel Economy (CAFE) standards. This combination of high prices and new regulations revolutionized fuel economy interest in the car market. "Since 1974 new car economy has been increasing dramatically," Fig.4-5. It almost doubled from 1974 to 1982.

But now, "...it appears that the steady march of improving new car economy is in jeopardy." For the first time, both GM and Ford are predicting that they will not meet the CAFE standard of 26.0 mpg average in 1983, falling below by about 2 mpg. Chrysler expects to achieve 27.5, while AMC projects 31.6. After factoring in all the weighted expected sales of domestic and foreign models, Greene concludes new car fuel economy will decline for the first time since 1974.

Part of the impressive new car fuel economy shown in Fig.4-5 is preference for smaller cars. Most, however, is due to engineering and manufacturing changes, and most of that due to decreased car weight within car classes. From 1978 to 1981, the average inertia weight of new cars reduced from 3627 to 3155 pounds, 472 pounds, or 13%. Of the total fuel economy improvement, 54% was due to this weight reduction. The next most effective change was reduction in performance and engine power, thereby reducing the horsepower/weight ratio by 9%. This reduced fuel consumption by an additional 18%. Improved automatic transmissions and more use of manuals accounted for a further 13%; improved aerodynamics for 9%; and increased use of diesel engines contributed the final 6%.

Very little improvement is from technological advances; most is due to downsizing, performance reduction and changing of transmissions. Greene concludes these improvements are largely reversible and, in a declining fuel price picture, could lead to a swing in customer preference, making the future difficult to predict with confidence.

He also points out that, "While total use of distillate fuel is now 15 percent below its 1973 level, transportation use of distillate fuel has increased substantially. Transportation consumption in 1981 was over 20 billion gallons annually, a 38 percent increase over 1978," 1982 data will be only slightly lower than 1981. "Virtually all this increased importance has been a result of expanding use of diesel fuel in highway transport." His historical record of this growth is shown in Fig.4-7. "According to Federal Highway Administration statistics, highway use of diesel fuels more than tripled between 1965 and 1982." Non-highway use increased about 50% in the same period.

The important thing is that, "Within the highway mode heavy trucks use almost all the diesel fuel. Although virtually all buses with the exception of school buses use diesel fuel, total bus use amounts to only 3.3 percent of total transportation distillate use. In 1980, automobiles and light trucks accounted for only 2.7 percent of transportation distillate, but their usage has been growing rapidly. Diesel use by automobiles and light trucks was probably twice the estimated 1980 level in 1982 and will approach three times that level in 1983. Because autos and light trucks consume almost seven times as much gasoline as all diesel fuel use by heavy trucks and buses, even relatively

small increases in light vehicle dieselization can have a very dramatic influence on total highway diesel fuel use. In the next two decades light duty vehicle dieselization will be the most significant unknown factor in the use of diesel fuel in transportation."

"Most of the growth in highway diesel fuel use since 1950 occurred as a result of the increasing numbers and dieselization of heavy trucks...heavy truck stock approximately doubled in the decade and a half...At the same time, use of diesel engines in new heavy trucks increased from 50 to 90 percent...By 1982 over 99 percent of all new (heavy) trucks...had diesel powerplants."

"Interestingly, the gasoline to diesel transition occurred primarily prior to 1973 at the time when fuel prices were low. The greater durability and lower maintenance costs of diesels were probably more important factors than the lower prices for diesel fuel and inherently greater fuel economy...The historical increase in heavy truck dieselization caused diesel heavy truck stocks to quadruple from 1966-1980...At the same time the demand for intercity truck freight transport, the predominant use of heavy trucks, increased by only a little over 50 percent...about the same annual rate as gross national product...it was the growth of heavy truck stocks, the dieselization of the heavy truck fleet, which caused a tripling of highway diesel use between 1966 and 1982."

"In the future, it is reasonable to expect heavy truck stock and heavy truck diesel use to increase roughly in proportion to the growth of intercity truck ton-miles, which have historically grown roughly in proportion to Gross National Product. Dramatic future increases in highway diesel use, then, could not come as a result of heavy truck use, but would require substantially increased dieselization of other highway vehicles."

"Medium weight trucks...are not likely to be a major factor in the future growth in highway diesel use because of their small share of total energy use...increased dieselization of medium and light-heavy trucks has increased diesel use by...about one percent over the past five years."

"Only 5 percent of highway diesel use is consumed by buses. Essentially all intercity and local transit buses are powered by diesel engines. School buses which comprise only one-third of bus energy use, consume almost exclusively gasoline. Energy use by buses has increased only slightly over the past two decades...commercial bus energy use will continue to grow slowly, if at all, in the decades ahead. The potential for fuel switching is likewise limited...Even if all the school buses were converted to diesel engines diesel fuel use would increase by only about 2 percent."

"There were 6.3 million heavy duty trucks and buses in use in the U.S. in 1980, but there were 134 million automobiles and light

trucks." Accounting for differences in consumption rate and mileage, heavy duty vehicles still account for less than 1/5 of total highway fuel use. Only 2% of the present light vehicles use diesel engines. "The potential for light duty vehicle dieselization is obviously enormous." This 2% of light vehicles in 1983 will probably consume 7-10% of total highway diesel fuel use. "...Dieselization of 25 percent of light duty vehicles would double highway diesel use."

"Sales of diesel automobiles and light trucks did not become significant in the United States until 1978 (Fig.4-8) and they peaked in 1981 as units. About as rapidly as they rose, diesel sales declined in 1982 and 1983 as gasoline prices declined and the price advantage of diesel fuel was simultaneously reduced." See Fig.4-8. If gasoline prices rebound, diesel sales should pick up, but how much of the market they can capture depends not only on economic factors and customer preference but also on..."the largely unresolved environmental issues surrounding light duty diesel particulate emissions. How these two factors develop will determine whether highway diesel fuel continues its rapid growth or stabilizes, growing at or close to the rate of the GNP."

"If one assumes that new car fuel economy improvement is responsible for about 60% of fuel demand reduction to date, reduced travel and operational efficiency improvements about 25%, and smaller vehicles about 15%, then it is possible to crudely estimate that the 'reversible' portion of the fuel economy to date...no more than one-third of demand reduction to date can be attributed to technological improvement. Indeed, probably a great deal more than two-thirds is reversible by persistently lower fuel prices."

"The only factor holding down demand is the still substantial difference (about 10 mpg) between vehicle stock and new vehicle economy...If lower prices persist for any substantial length of time (such as occurred in 1975-78) new car fuel economy improvement will stop and may even decline. If this occurs, vehicle stock economy will be insufficient to restrain demand. In contrast, diesel fuel use has increased rapidly during the past decade despite price increases equal to those of gasoline...(but) the historical rate of increase in diesel consumption can only be sustained by dieselization of medium and light trucks and automobiles. Recent diesel sales declines in each of these vehicle types is indicative of the fuel price sensitivity of diesel market shares for lighter vehicles."

"Without substantial petroleum price increases to spur light duty vehicle dieselization, it seems unlikely that highway use of diesel fuel will grow faster than the economy as a whole."  
(Emphasis added-Ed).

This chapter assumes that U.S. automotive equipment will continue to be powered by the conventional fuels, gasoline and diesel.

Alternative automotive fuels such as LPG, CNG, LNG, methanol, ethanol and hydrogen are discussed in Chapter 7.

## Highway Motor Fuel Use 1970-82

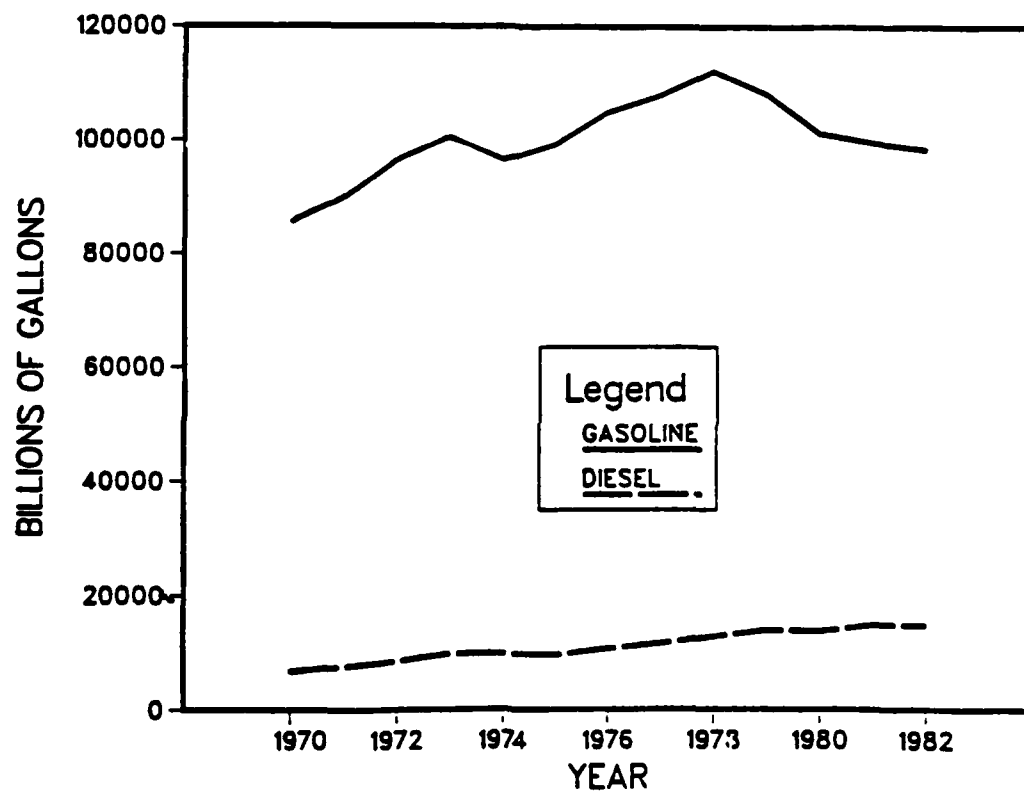


Figure 4-1

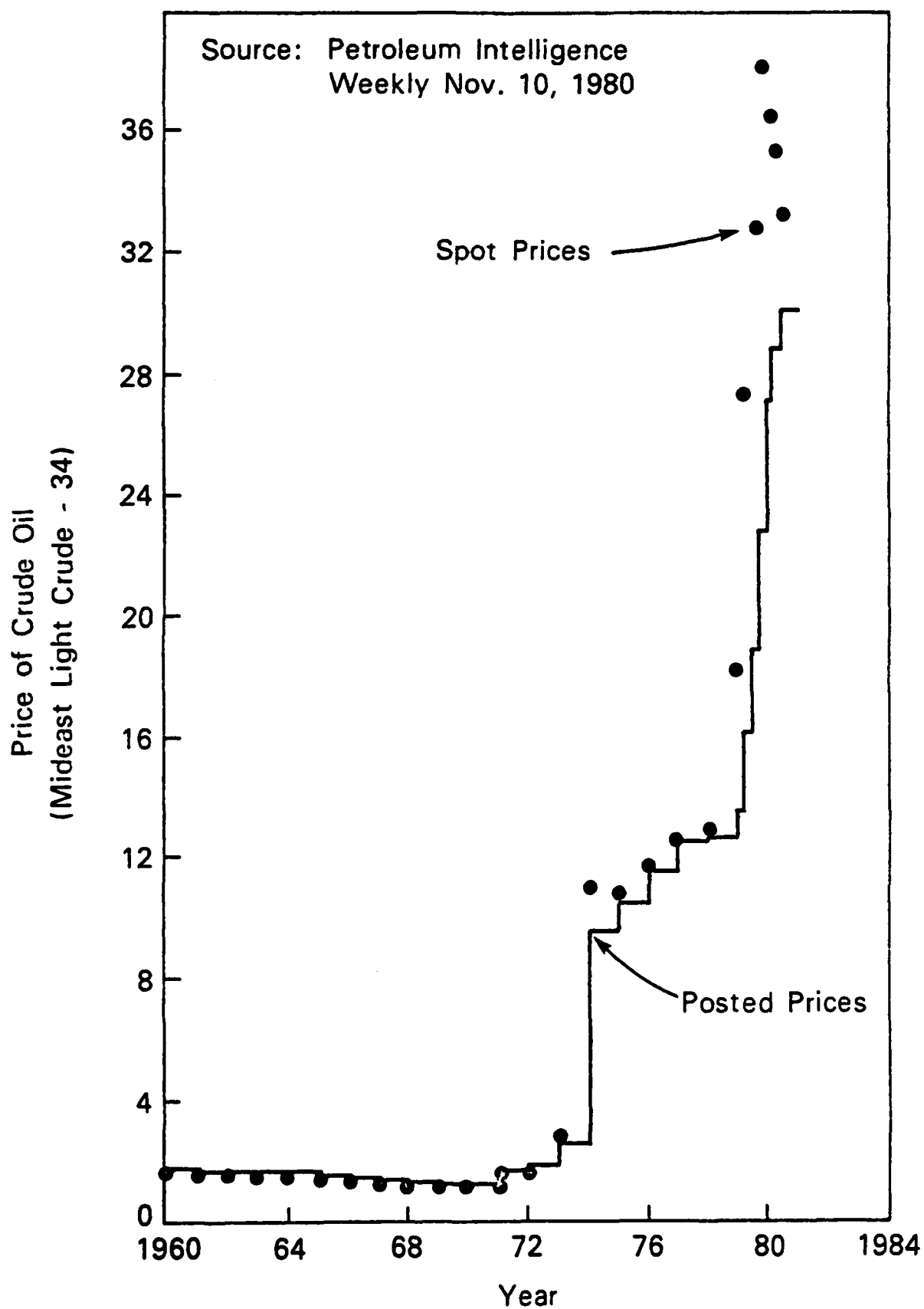
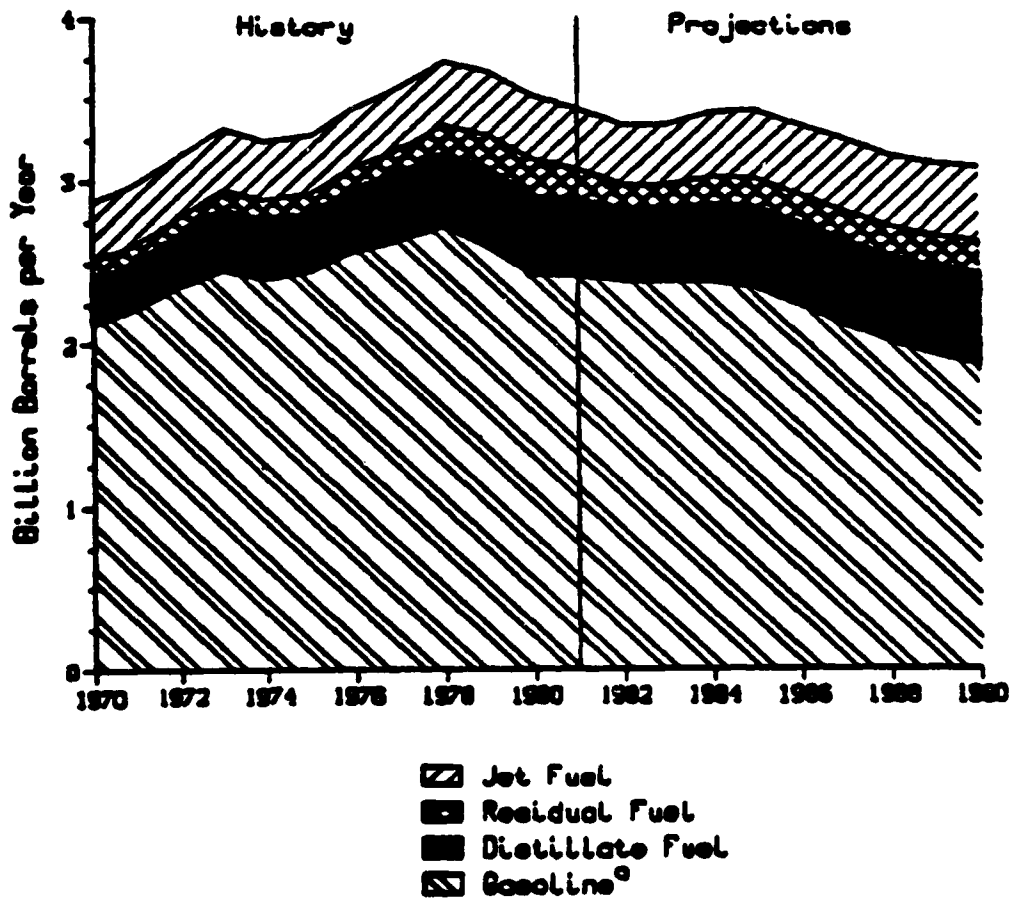


Figure 4-2

Transportation Petroleum Use,  
Midprice Scenario, 1970 to 1990  
(Billion Barrels per Year)



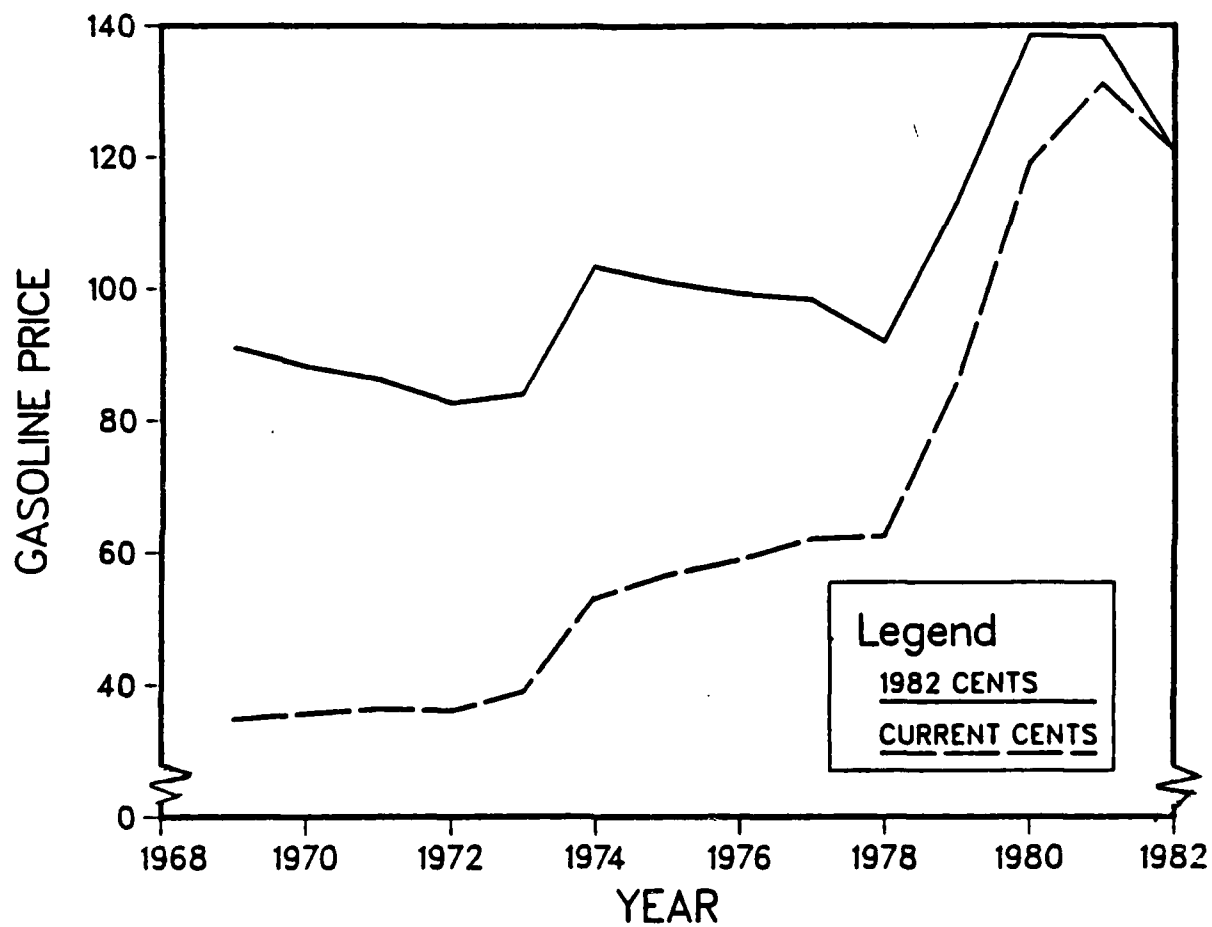
<sup>a</sup>Motor and aviation gasoline.

Note: Transportation use of liquified petroleum gases does not exceed 0.01 billion barrels per year and is not shown in the figure.

Figure 4-3



## Gasoline Prices in Current and Constant 1982 Cents



Trends in Vehicle Usage

Figure 4-4

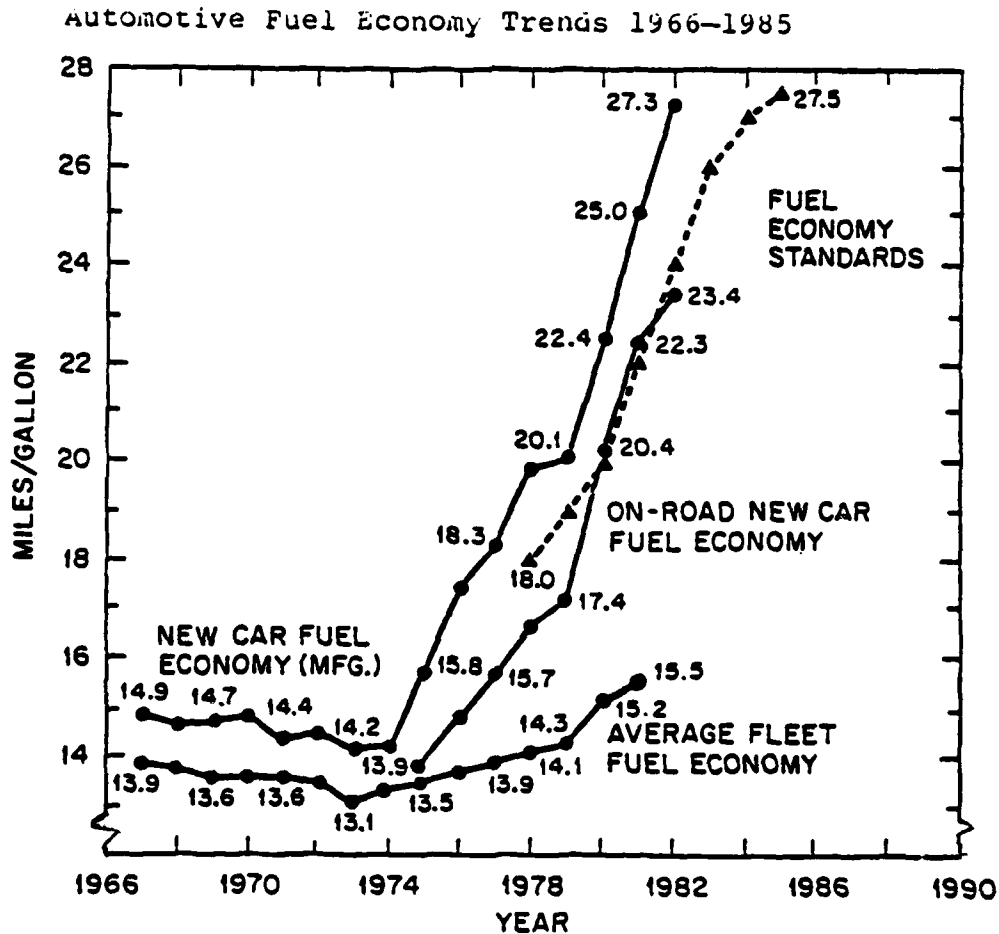


Figure 4-5

Source: Holcomb, M. C., D. L. Greene, G. F. Roberts, "Motor Vehicle MPG and Market Shares Report," March 1983, Transportation Energy Group, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

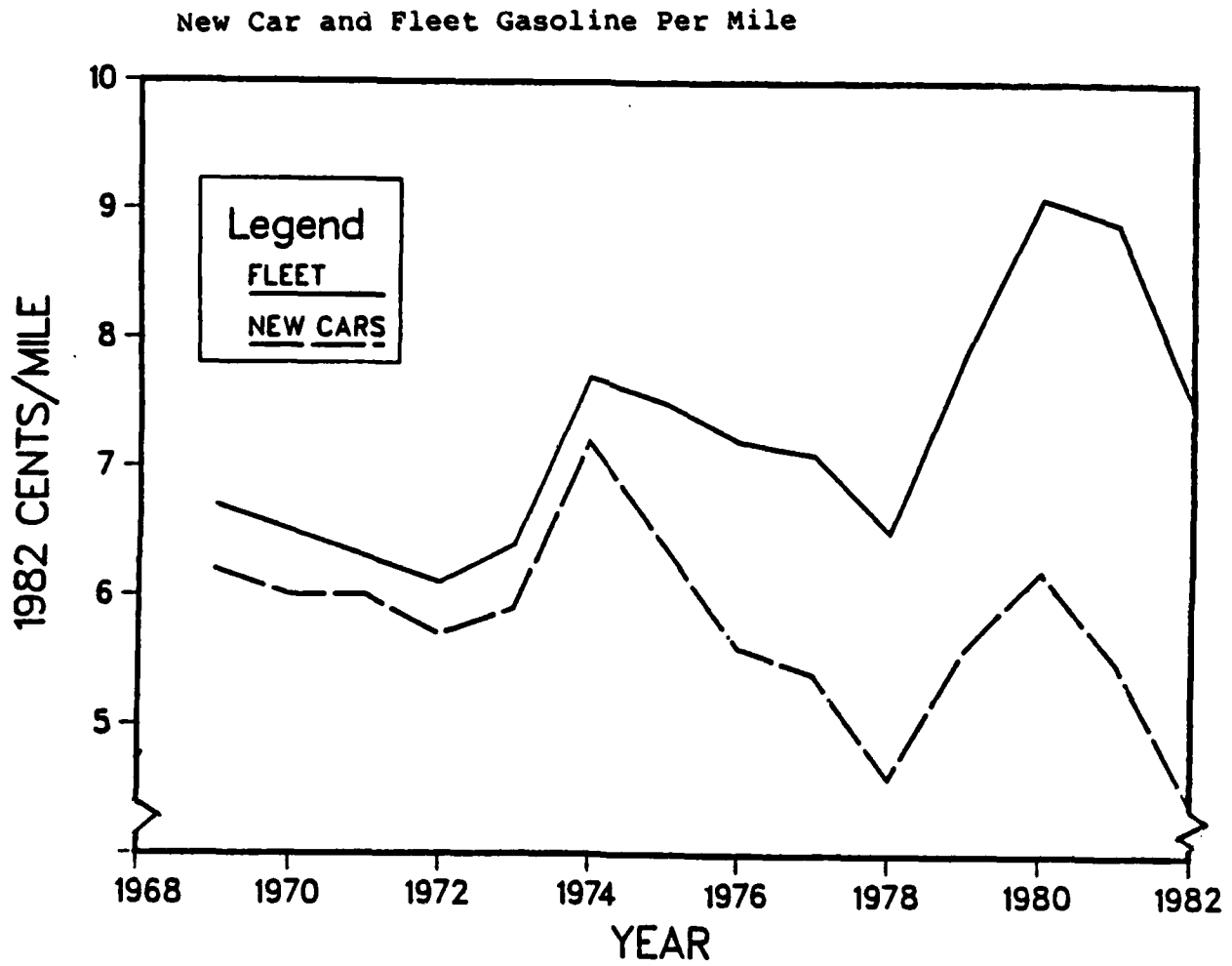


Figure 4-6

## Growth in Transportation Use of Distillate Fuel 1964-1982

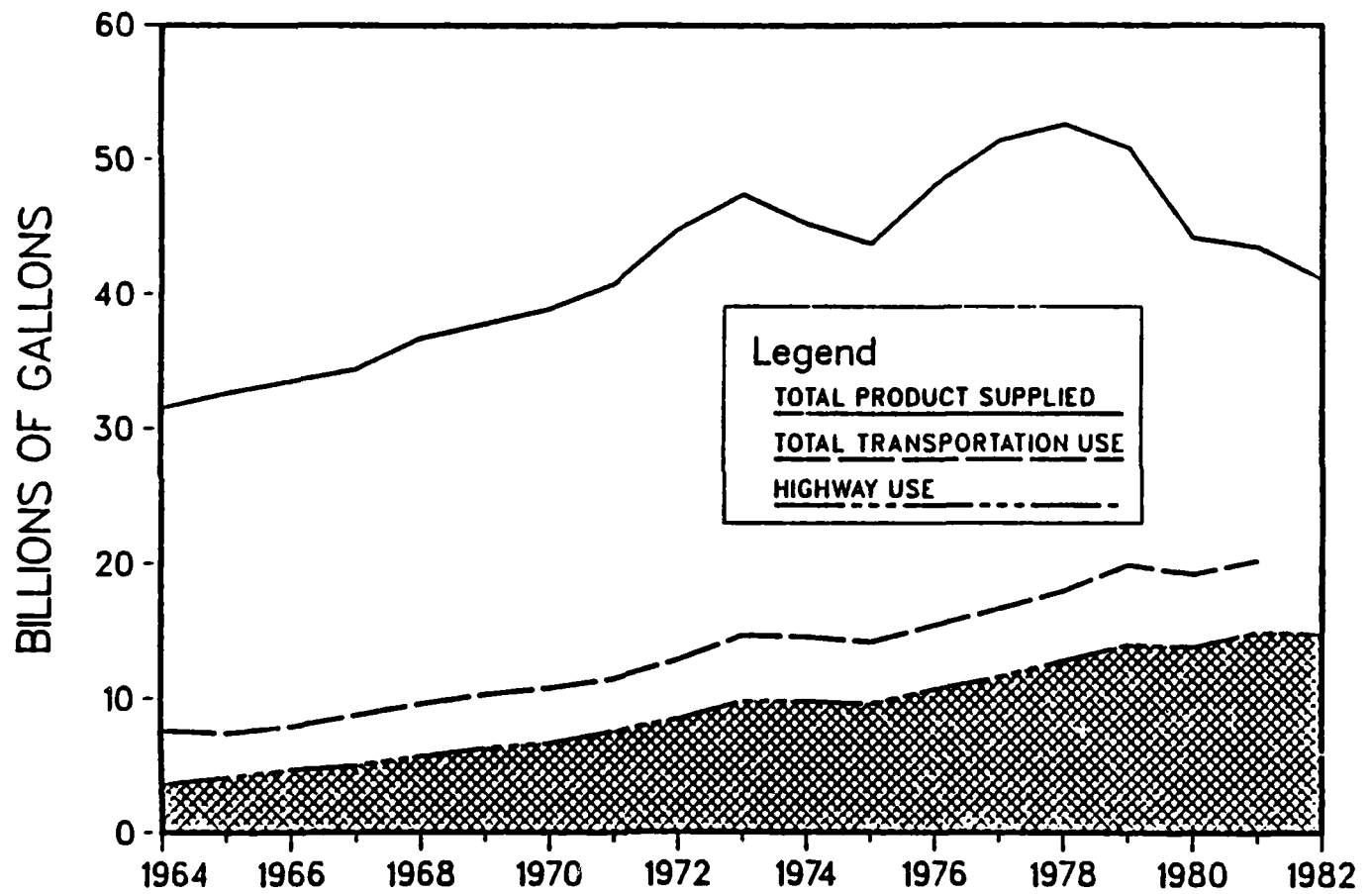


Figure 4-7

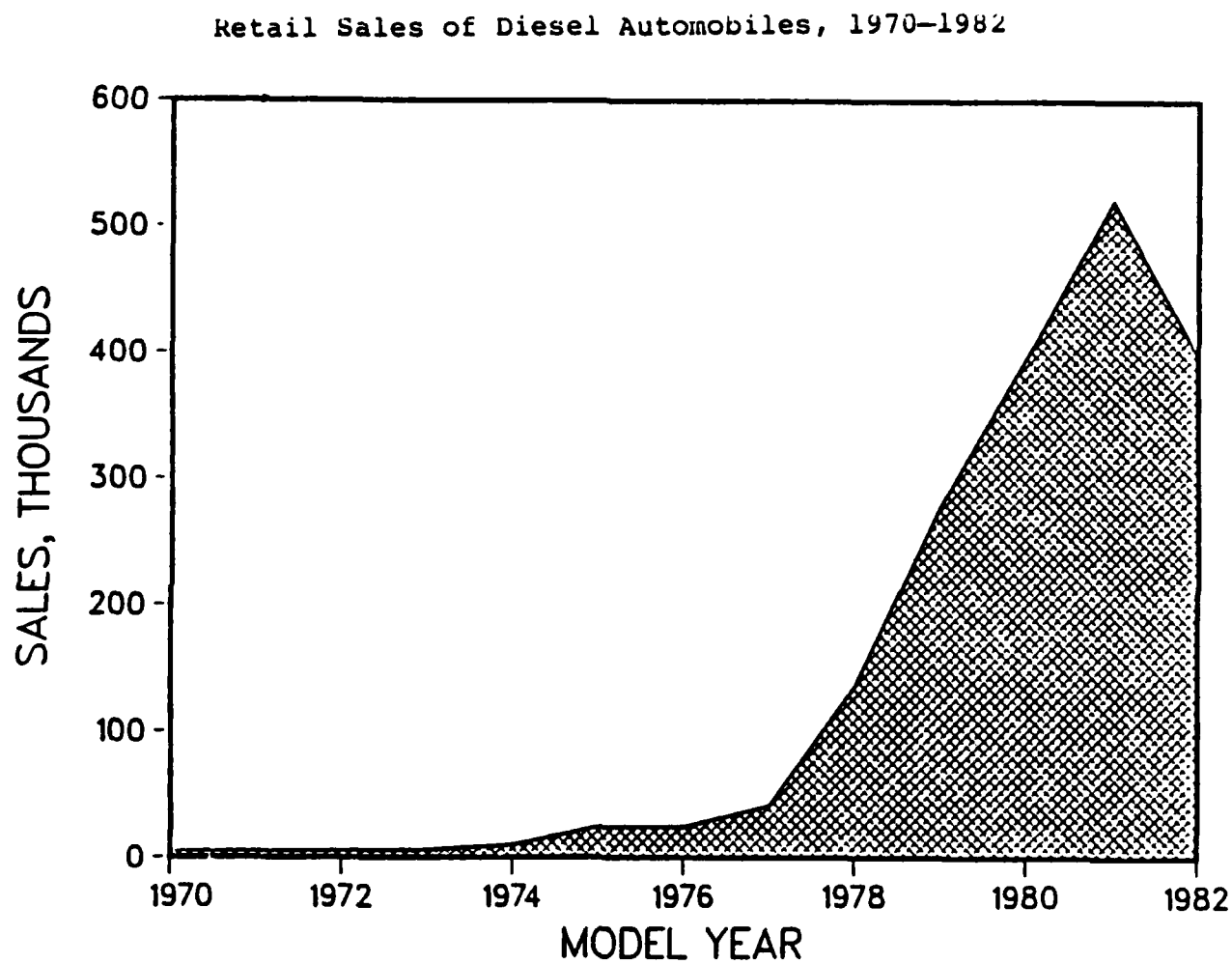


Figure 4-8

## Chapter 5

### Aviation Fuel

The U.S. aviation jet fuel consumption history from 1970 through 1981 and projection from 1981 through 1998, which is consistent with the DOE Energy Information Administration (EIA) world, U.S. national, and U.S. automotive fuel projections of Chapters 2, 3, and 4, was shown in Fig. 4-3, and is repeated here as Fig. 5-1. This chapter discusses that forecast in comparison with forecasts from the International Civil Aviation Organization (ICAO), the FAA's Current Market Outlook, projections by Boeing and Douglas aircraft companies.

The ICAO forecast reviewed here is that presented to the 24th Session of the ICAO General Assembly, September 20-October 18, 1983 in Montreal, as Agenda Item 19: Future Availability of Aviation Fuel. During agenda review, the paper was identified as (Working Paper) A24-WP/9. The U.S. Position was that, "The U.S. shall support A24-WP/9. The U.S. Delegation supports ICAO's continuing efforts to monitor the aviation fuel situation." The U.S. Delegation does comment:

"Paragraphs 15 and 17 of A24-WP/9 present logical expectations of fuel availability, aviation fuel conservation and future fuel prices. In paragraph 18, however, the World Bank was referenced as having assumed that there would be no change in real price between 1982 and 1985. Prices have since fallen and, in the absence of some severe disruption in world crude oil supplies, are expected to remain soft until and when the world economic recovery increases its demand for fuel, in probably two or three years."

"There is a potential risk which A24-WP-9 does not mention. In case of a severe disruption of world crude oil supplies, many analysts believe that the price of crude oil will double. In the recent International Energy Agency (IEA) exercise, Allocation System Test 4 (AST-4), in which the U.S. supply was reduced hypothetically by one million barrels per day (about 6%), the price of crude oil jumped to \$98 per barrel. States should be aware of this potential consequence and remain alert to the possibilities for interruption of world-wide crude oil deliveries."

With respect to AST-4, Chairman Phillip R. Sharp, House Subcommittee on Fossil and Synthetic Fuels, in opening the hearing of June 30, 1983, commented, "In a simulated oil crisis, under which the oil sharing arrangements of the IEA were triggered, the hypothetical price of oil rose to \$98 per barrel. An SPR drawdown policy that handles an emergency by tripling oil prices, even temporarily, is a prescription for disaster."

In The Washington Post of September 19, 1983, writing in, "Oil-Crisis Test Yields 'Economic Disaster'," Milton R. Benjamin opens with, "In the most realistic test of how the U.S. government would deal with a new world oil crisis, the Reagan administration's free-market approach turned an oil shortage into a national 'economic disaster' according to reports by 10 states that participated." "The threat of such a thing happening is very serious. And I'm not talking about six months from now. I'm talking about six weeks," said James Adkins, a Middle East expert and former ambassador to Saudi Arabia, who forecast the 1973 oil embargo."

In Time magazine, October 3, 1983, "Over a Barrel," by Kenneth M. Pierce, reports with respect to AST-4, "To the dismay of most participants, during the hypothetical crisis the U.S. Energy Department did not move to control supplies or limit the price of oil. As a result, U.S. prices zoomed to a theoretical \$98 per bbl., with gasoline priced at \$2.38 per gal."...."A second study, completed in March by the Congressional Research Service, confirmed that the 'ceiling' could go as high as \$130. per bbl. in a crisis. If one had erupted in 1982, the study concluded, the gross national product of Western nations would have dipped by an additional 8%."

These matters are discussed further in Chapter 9. As a matter of interest, the Department of Defense, the FAA, and NASA have asked the Georgetown Center for Strategic and International Studies to convene a symposium of about thirty recognized foreign-affairs analysts to review their opinions on the probability of world crude-oil disruptions. The symposium will be held in November, 1983; it is also discussed in Chapter 9.

#### Future Availability of Aviation Fuel - ICAO, September 1983

A24-WP/9 is a duplicate of AT-WP/1403 of December 24, 1982, prepared by the ICAO staff. It reports world energy and oil consumption 1975-1981, giving average annual growth rates; world distribution of oil, 1981 by six major world regions; distribution of world imports and exports, 1981 (crude oil and refined products); distribution of jet fuel, 1980 by the six world regions; and refinery output of market economies, 1980 in terms of aviation gasoline, motor gasoline, kerosene, jet fuel, distillate fuel oil, residual fuel oil, lubricants, and other products.

It also discusses the history of world oil demand and supply, price trends, aviation fuel production and efficiency in the use of aviation fuel. Under Conclusions and future prospects it comments that the outlook for aviation fuel has not changed since the 23rd General Assembly. New crude discoveries have broadly kept pace with consumption. Fuel substitution should continue to

relieve pressure on demands for oil and ease long-term aviation supply. (This is contrary to EIA's NEPP-1983, which forecasts more U.S. switching from natural gas back to oil-Ed.).

It notes that aviation fuel requirements are relatively small compared with total world oil requirement, but, "...expected to increase at a higher rate than the overall demand for oil, mainly because air transport is expected to continue to grow more rapidly than the world economy." Significant improvements in fuel efficiency are expected for air transport. "Previous assessments that improvements in fuel efficiency could approach 20 per cent over the 1980 to 1990 period and that further improvements of the same order should be possible in the 1990s (Circular 149-AT/52 should be achievable, given the resumption of traffic growth and associated fleet modernization."

It finds no instances of unfair or discriminatory practices in the supply of fuel reported since the last Assembly.

Referring to the International Energy Agency (IEA) forecasts, ICAO expects, "...real oil prices to fall at between 3.3 and 3.9 per cent per annum between 1980 and 1985. After 1985, the range of anticipated price trends extends from a constant real price rise to a rise of 3 per cent per annum. Under these various assumptions (and others related to economic growth and oil supplies), the IEA study concluded that an imbalance between supply and demand for oil may appear in the second half of the 1980s or in the 1990s, leading to further price increases and market disruptions."

The ICAO paper notes that World Bank did not expect the fall in oil price in 1982 to affect the long-term upward price trend, "...which was determined principally by rates of economic growth in industrial countries and oil production level. The World Bank's 'most likely' assumption was for no change in real price between 1982 and 1985 with increases of 2.5 to 3 percent annually thereafter." These rates derived from IEA and the World Bank are shown in Fig. 5-2 to compare well with the EIA forecast.

ICAO concludes, "These anticipated developments may be expected to result in adequate supplies of aviation fuel being available at price levels which will not seriously hinder the growth in air transport over the 1980s and 1990s." By including the caveat on the probability of world crude oil disruption, this author agrees.

#### FAA Fuel Forecasts - 1983-1984

Because of the 1981 controllers' strike the release of FAA's Aviation Forecasts has been moved from its traditional October of each year to the following February. Consequently, the 1983 issue



was released in February 1983, while the 1984 issue will now be released in February 1984. Each is more practically indexed to its previous year; that is, the 1983 issue is necessarily based on 1982 data. This shift should therefore be noted as a change in timing between the previous FAA data reported in the Impact report and this report on U.S. Energy: Aviation Perspective.

FAA's forecast of the Gross National Product, Consumer Price Index, and Fuel Price Index are based on analysis of forecast data from Chase Econometrics, Data Resources, Inc., Evans Economics, Inc., and Wharton Econometric Associates. "Aviation activity is expected to reverse three straight years of losses in 1983, reflecting a return of the Air Traffic Control normalcy and an upturn in economic activity." There is some argument as to whether the ATC has returned to normalcy.

Actually, airport arrival and departure capacity is still limited at some locations. But the FAA has redistributed its controller manpower to completely restore capacity in all the enroute centers (Air Route Traffic Control Centers - ARTCCs) and at all of the high-volume airports. Airport operating capacity continues to be limited by the runway and facility capacities of some individual large terminals, but not by ATC. At some of the smaller airports, commuter and private flights may still experience some capacity inconvenience due to manpower shortage. But in the scale of national aviation fuel consumption, it is fair to say that the ATC system has fully returned to normal.

FAA's 1983 Forecast, however, could not foresee the 1983 lower rate of economic recovery, developments in the airline bankruptcy/labor interruptions, or effects of below-cost fares on airline revenues. The Forecast therefore predicted that the GNP, adjusted for inflation, would grow at an average rate of 3.1% from 1982-1994 and domestic air carrier revenue passenger miles would increase at 5.1 percent annually from 1982-1994. The number of operations (flights), however, has expected to grow by only 1.8%, due to shift toward larger aircraft and longer trip lengths (for the air carriers; commuter carriers are classed with general aviation). The Forecast assumed a full economic upswing by 1984, with economic growth expected at between 3.4 and 5.0%

Commuter carriers were forecast to enplane 5.8% of all fare paying passengers in 1983 and, by 1994, to increase their share to 8.1%. Commuters and air taxis were expected to nearly double the volume of their operations between 1982 and 1994. Nevertheless, because of short ranges and small aircraft, their contribution to fuel consumption is smaller than their passenger carriage would indicate.

While Forecast 1983-1984 noted at its publication that there was already considerable disagreement on the strength of the national economic recovery, at that time FAA expected fuel prices would resume their upward trend in 1983, but at a rate slower than the economic recovery. It can be assumed that the 1984 report will revise that estimate further downward. In fact, the Wharton material for Forecast 1984-1985, which shows about an 8% drop in fuel prices in 1983, predicts a larger drop, to a total of about 10% below inflation, for 1984. Wharton's fossil Energy Price Index forecast for September 1983 is shown in Fig. 5-3. From 1987 through 1993, Wharton predicts fossil fuel will rise 1.5% per annum faster than the GNP implicit price deflator.

Wharton now incidentally, "...projects a modest OPEC price increase of \$1 per barrel by mid-1984---," despite continuing excess production capacity in the Persian Gulf."

FAA also expected a sharp upturn in aviation activity in 1983, which no doubt will also be revised downward.

Combining all the factors of aviation traffic, aircraft sizes, passenger load factors, trip length, ATC delays, fuel conservation, etc., the FAA Aviation Forecasts - 1983-1994 prediction of total U.S. domestic fuel, in millions of gallons, is shown in Fig. 5-4, where it is compared with EIA's estimates from their 1982 Annual Energy Outlook. (Some of the difference between FAA and IEZ is in conversion from BTUs to gallons of jet fuel). Aviation Fuel Price Index forecasts (Indexed to CY 1972) by Chase, DRI EVANS, and Wharton for the 1983 report, are given in Fig. 5-5. Also shown is Management and Budget (OMB) Oil and Gas Deflator (Base 1972) for 1984. FAA will probably use these OMB data in the FAA Aviation Forecasts - 1984-1995.

### Boeing

From Current Market Outlook, March, 1983, Boeing projected World GNP growth at 3.1% average 1982-1995 and U.S. growth at 2.8%. However, as shown in Fig. 5-6, this average is far from constant, with a rapid recovery from a negative GNP in 1981 to a range of 4-6% growth in 1984. Boeing's corresponding CPI inflation for the U.S., Western Europe, Canada and Japan are given in Fig. 5-7, where U.S. inflation is nearly constant at just over 5% from 1982 through 1986.

Boeing's world and U.S. airline fuel consumption forecasts through 1995 and 1990, respectively, are given in Figs. 5-8 and 5-7, where the trends are seen to agree well with ICAO and others. Boeing's estimate of airline fuel consumption efficiency of Fig. 5-10 shows a fleet improvement from about 41 ASMs/gal (Available Seat Miles/gal) in 1983 to 43.5 in 1990, indicating an improvement of

only 6%. This seems to indicate a lack of optimism on deployment of new, more efficient aircraft like 757, 767, and DC-9-80.

As seen in Fig. 5-1, Boeing expected the real price of jet fuel to increase over 1982 by about 15% in 1990 and 35% in 1995, with a question on its trend in 1983 and 1984. No doubt their current opinion has been modified by the recent continuing downward trend in jet fuel prices.

In Dimensions of Airline Growth, also March 1983, Boeing outlines GNP growth rates for various parts of the world from 1970 to 1982, including an interesting comparison of the U.S. GNP with the cycle of clipper ships, railroad ton-miles, motor vehicle registration, and airline domestic airline RPM. It also shows system jet fuel costs, jet fuel prices, OPEC annual average prices, and airline fuel consumption efficiency gains from 1960-1982. Although it outlines Boeing's forecast methodology and shows a forecast flow diagram, Dimension of Airline Growth does not forecast any of these quantities into the future. Therefore, the report is convenient for those who would like to project their own forecasts, but not for comparison with other predictions. All the Boeing predicted material is given in Current Market Outlook.

#### McDonnell Douglas

McDonnell Douglas's The Outlook Book, 1983, is subtitled, "An Analysis of World Economies and Passenger and Freight Forecasts Through 1990." It includes a world economic outlook, a regional economic outlook, an air traffic outlook and a discussion of high-priority world logistics. It also contains an, "Energy and Jet Fuel Outlook," with quantitative information and interpretation on oil price and production developments from 1979. While it points out that the price of oil in 1981 was high for the U.S., because of the dollar's unexpected strength (with the OPEC price quoted in dollars) it placed a much greater financial strain on the rest of the world.

It points out that, with total oil consumption in the non-Communist world falling about 12% over the past three years, a much steeper slide (than from \$34 to \$29) in the OPEC price might have been expected. Particularly with U.K. and Mexican production increased and with drawdown in oil inventories, OPEC production dropped to its level of 1968. With a general decline in other commodity prices, oil buyers expected OPEC might not be able to reach an agreement, particularly one that would be compatible with the U.K. and others.

The report points out that with oil then at \$34 a barrel, although OPEC managed to hold below its production of 17.5 MMBD agreed in its March, 1982 conference, during March, April, and May, 1982,

for the last seven months of the year, OPEC produced at about 18.82 MMBD. At Vienna on December 20, 1982, OPEC raised its quota to 18.5 MMBD, but took no further action, and many oil buyers saw the result as an indication that a price drop was impending, particularly as spot prices were falling at the time.

Following an informal meeting of seven OPEC oil ministers in Bahrain in early January, 1983, OPEC called an emergency meeting for January 23, when Sheikh Yamani of Saudi Arabia told the press the meeting had been a "total failure." There followed a series of meetings including OPEC and non-OPEC producers, which led to a further drop in OPEC purchases and further speculation that prices would drop drastically; some expected it could fall as far as to \$7 a barrel in 1983 dollars. This activity finally led to the March 1983 meeting in London, where the reduction to \$29 was agreed upon.

At the time of their report, McDonnell-Douglas regarded the \$29 price as being threatened but, because of growth in U.S. GNP in the first quarter, 1983, the prospect was looking better. "Every 1% increase in GNP results in an increase in petroleum demand of about 0.6% for the U.S. and Europe and about 1% for less developed countries. The world average is between these values." McD-D also expected the value of the dollar to fall and reduce pressure on oil purchases outside the U.S., essentially reducing the price of oil further for those markets. However, the dollar and U.S. interest rates have not yet fallen much since their report.

McD-D assumes that the \$29 price will hold during 1983 and that, accordingly, real prices will drop almost 11.6%. Nominal prices will then hold steady through 1984, climb slightly more than 5% in 1985, and will increase at a rate between 6.9% and 8.7% for the years between 1986 and 1992. Removing inflation provides that the real price will decline 15.5% in 1983, fall an additional 4.2% in 1984, and remain essentially unchanged in 1985. Real price increases are then expected of 1.6% in 1986 and 3.6% in 1987, with the rate through 1992 running at just under 3% per year.

Jet fuel prices in the U.S. fell in late 1982 and early 1983, with some spot cuts as much as 20% for a time. McD-D does not expect these cuts to continue, although prices have drifted somewhat further since their report. Refinery profit margins have been unusually low. "Traditionally, the least price-elastic product - in today's market, aviation kerosene - is subject to the greatest increase in refinery margins when demand rises."

In real terms, with the GNP deflator applied, their prediction is for a 15.8% fall in 1983, a 4.2% decline in 1984, no change in 1985, and between 1986 and 1992, real price increases will range between 2.6% and 3.9%. As in all forecasts, the future is

generally more tranquil than the present and recent past. "By 1992 the price of jet kerosene, in real terms, is predicted to be about its 1982 level, still under its record 1981 real price."

McD-D's predictions for crude and Jet kerosene prices are given in Fig. 5-11.

### Fuel Quality

Apparently all forecasters of crude oil trends agree that future world crude oil supplies will be of heavier quality than those of the past. That is, future crude oil stocks have been steadily trending toward higher boiling point content, less hydrogen in the constituents, with more sulfur, nitrogen, metals, and other impurities. With future wells drilled to greater depths and in less promising locations, this trend is expected to continue indefinitely in the future. Some light crude stocks will probably be found in future world oil exploration. But the opinion is overwhelming that the world average of crude oil quality will continue to fall steadily.

Straight distillation operations still dominate the world's refinery processes. By fractional distillation, a barrel of crude oil is separated out into its primary components: light liquids, gasoline, middle distillates, residual oil, greases, waxes and asphalt. By distillation, the barrel of crude can be divided only into the materials it already contains. If the crude oil barrel is "heavier," it will produce a larger proportion of heavy products. If a barrel of crude contains fewer components in the boiling range of jet fuel, a lower percent of jet fuel will be obtained from the barrel.

Many have seen this situation as an inevitable prediction that jet fuel, along with diesel fuel, other middle distillates, and perhaps the whole slate of petroleum products, will trend toward heavier levels. Recognizing that these heavy products can be cracked into lighter fractions, while light fractions may be synthesized into desired middle products, the opinion still prevailed that heavier fuels would be produced during times of fuel emergencies. Many refiners expected they would be faced with more inferior crude during shortages and that customers should be prepared to accept inferior products, at least in time of emergencies.

By comparison, Boeing shows in Fig. 5-14 how the customers' demands for petroleum products are expected to vary from 1982 to 2000. The demand for gasoline and distillate fuels is expected to increase substantially, while that for residual fuels should drop by almost half.

But now this chain of inevitability on crude oil refining appears to have been broken, or to be rapidly dissolving. Demand for automobile gasoline has declined dramatically, resulting in availability of lighter fractions that had previously been in strong demand. It now appears that the demand for highway diesel fuel (a direct competitor of jet kerosene) will not grow nearly as fast as predicted, although this is a new trend which may not yet be recognized and accepted. Developments in catalysts and refinery operations have proceeded rapidly and processes are becoming economically feasible which were too expensive in the past.

A major driving force has been the fading market for residual fuel oil, once a mainstay of refinery operations. Now the market for resid has fallen so far that it is a liability in refinery operations. It is difficult to find a place to store the resid to permit conventional refineries to continue their runs. Resid sells for lower prices than the crude from which it is produced.

Most refiners have now made major decisions to take the bull by the horns. Many of the smaller and less sophisticated refineries have been shut down and permanently withdrawn from operations as the demand for nearly all products has receded. New components or rebuilt refineries are being configured to yield a wide range of products from virtually any crude feedstock which can be imagined. Pre-processing of extremely heavy and contaminated shale oil has shown that it can be converted economically into a superior-grade feedstock.

Most important, these types of operations which were previously regarded as special and extra-cost, are being incorporated into routine operations. Some refineries will no longer produce any residual oil or other inferior products. By hydrotreatment and synthesis, their entire product slate will be in the high-value category. Some now indicate that there is enough flexibility in these processes that the product fuel specification may be effectively selected by customers.

In the light of these developments, it now appears unlikely that fuel customers will be faced with a proliferation of substandard products. Unless a very severe worldwide crude supply emergency occurs very soon and prevails for many months, it is difficult now to imagine how these inferior fuels will compete in the market. In a very few years, it may be impossible to find any such fuels in the market under any circumstances.

But the situation does appear to signal two cautions to aviation fuel users:

AD-A137 766

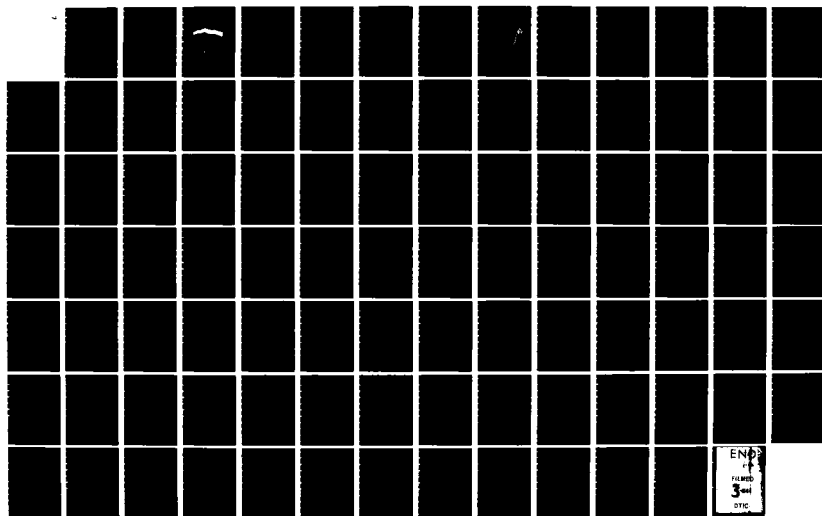
US ENERGY: AVIATION PERSPECTIVE(U) FEDERAL AVIATION  
ADMINISTRATION WASHINGTON DC OFFICE OF ENVIRONMENT AND  
ENERGY C L BLAKE NOV 83 FAA/EE-83/10

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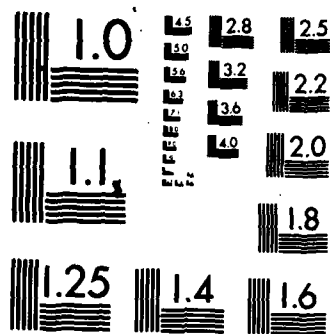
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MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A



First, with lighter components and products, it is possible that the flash point of future fuels may be lower. This is not inevitably true, because refiners indicate that synthesis may permit controlling the flash point better than in the past. But, with more naptha and other light components available, the aviation community should determine if it can be an economic advantage to accept fuels with lower flash points.

Second, many of these fuels expected to become available in the very near future, will in effect, be synthetics. Although compounded from petroleum molecules, if these molecules are cracked and synthesized as heavily as expected, they will be as foreign to natural petroleum molecules as synthetic liquid fuels produced from shale, coal, biomass, and the like. These fuels may either possess qualities not experienced in petroleum, or may lack qualities which are taken for granted in fuels distilled directly from petroleum.

It appears that the aviation community should review its fuel specifications to determine what type of new characteristics may be accepted, as well as what type of existing characteristics may be successfully omitted in future fuels. There may be a wide variety of "synthetic" fuels becoming available in the future. It would be desirable to consider the entire reasonable spectrum rather than to treat each new fuel as a unique specimen.

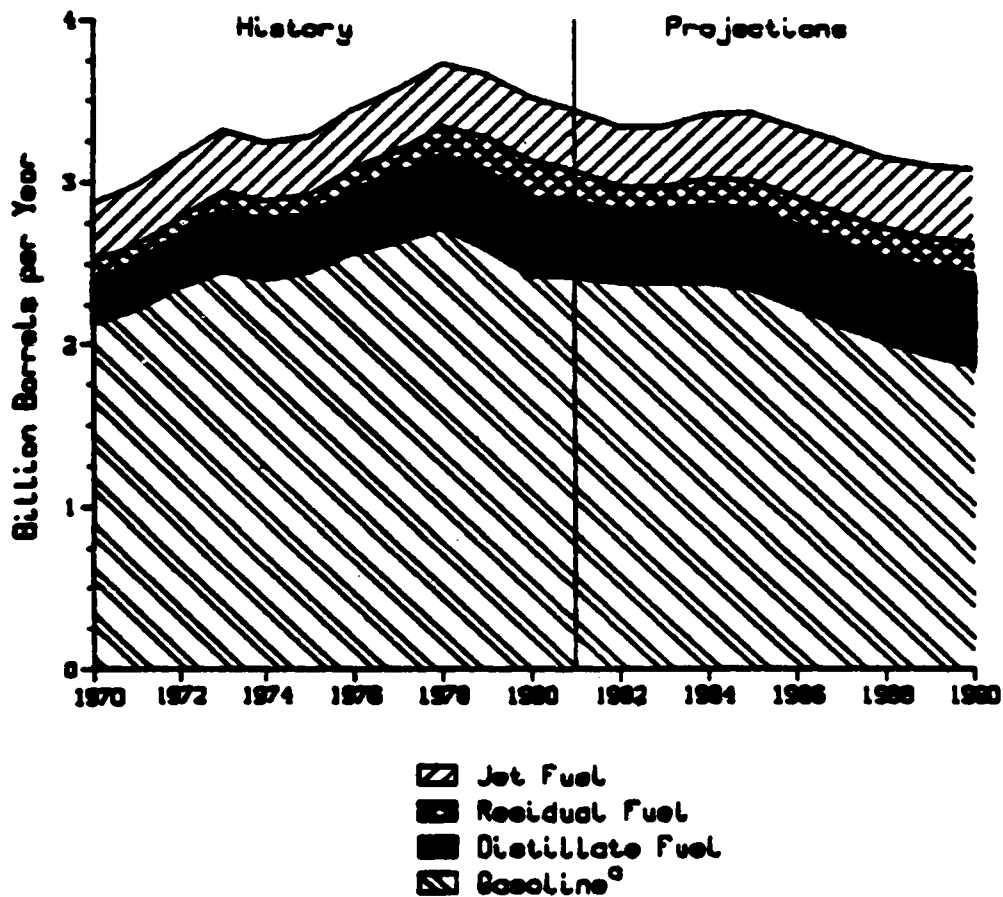
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5-2 Russell, Milton, "The Natural Gas Price Puzzle," Resources, February, 1983, Resources for the Future, Washington, D.C.

5-3 "The Natural Gas Market Through 1998, An Analysis of the Natural Gas Policy Act and Several Alternatives, Part IV," Energy Information Administration, DOE/EIA-0366, May 1983.

Transportation Petroleum Use,  
Midprice Scenario, 1970 to 1990  
(Billion Barrels per Year)

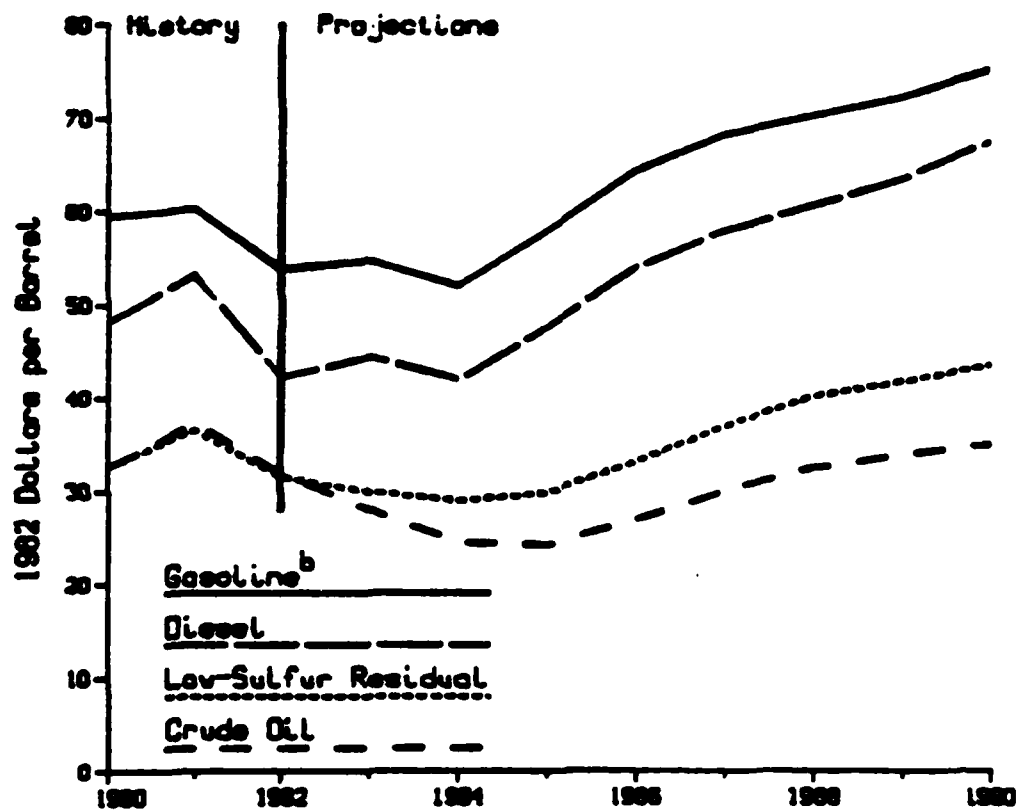


<sup>a</sup>Motor and aviation gasoline.

Notes: Transportation use of liquefied petroleum gases does not exceed 0.01 billion barrels per year and is not shown in the figure.

Figure 5-1

Prices of Crude Oil and Petroleum Products<sup>a</sup>,  
 Midprice Scenario, 1980 to 1990  
 (1982 Dollars Per Barrel)



<sup>a</sup>Prices shown are the refiner acquisition cost of crude oil and end use product prices.

<sup>b</sup>Weighted average price of all types of motor gasoline.

Figure 5-2

**Growth of GNP Implicit Price Deflator and  
Fossil Energy Price  
(Index, 1980=1.0)**

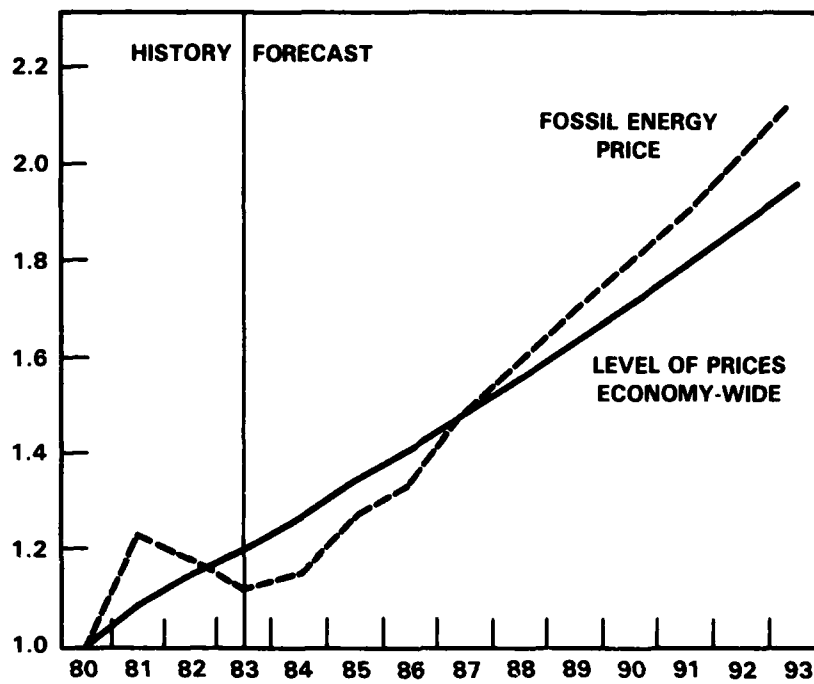


Figure 5-3

# *Estimated U.S. Domestic Jet Fuel*

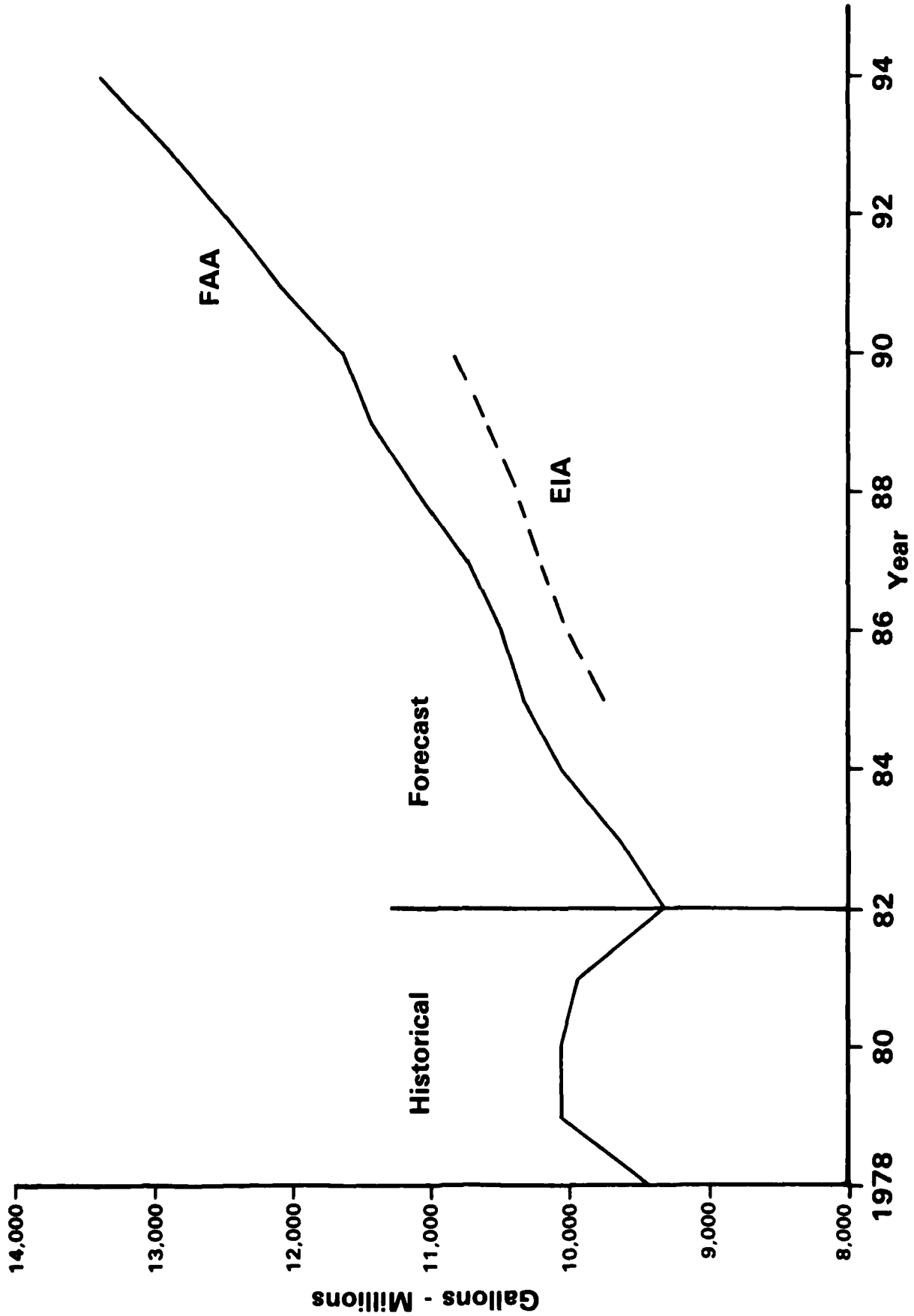


Figure 5-4

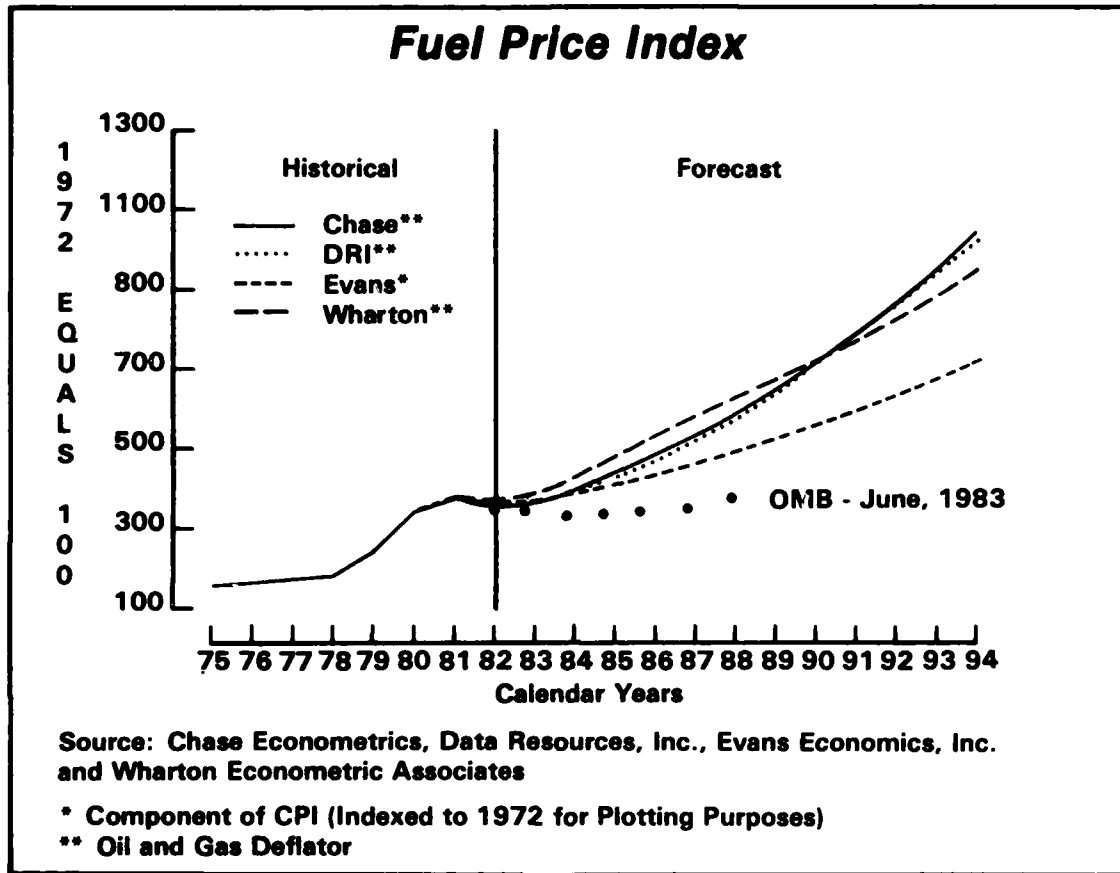


Figure 5-5

### Real GNP Growth for the U.S. 1975 Dollars

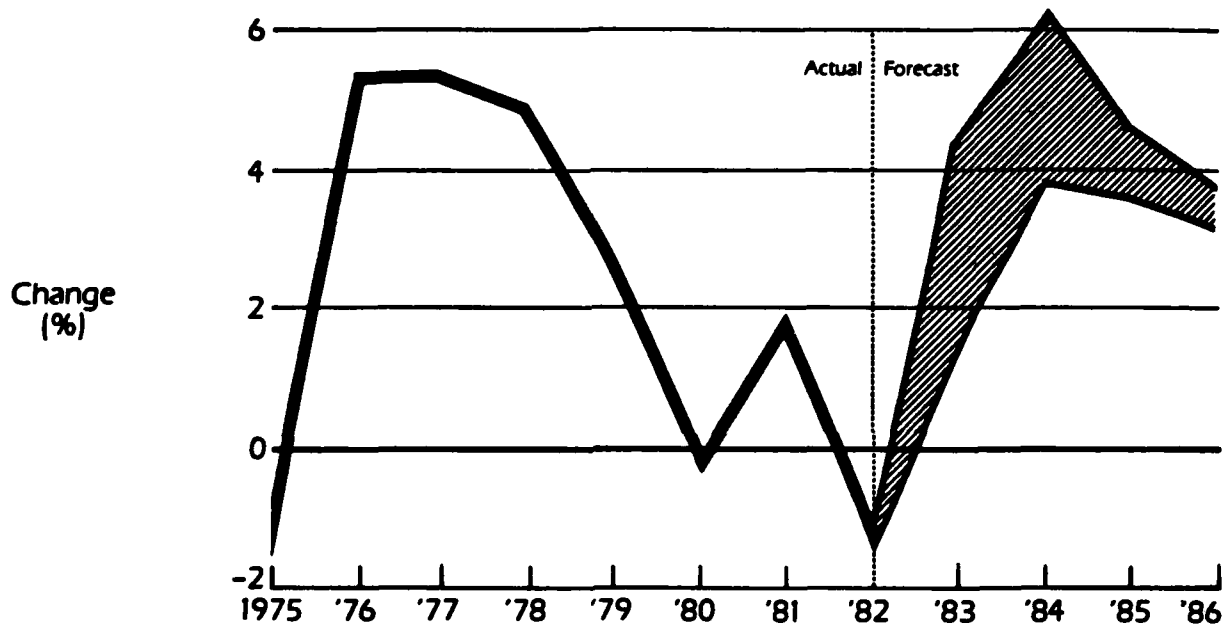


Figure 5-6

## Inflation (CPI)

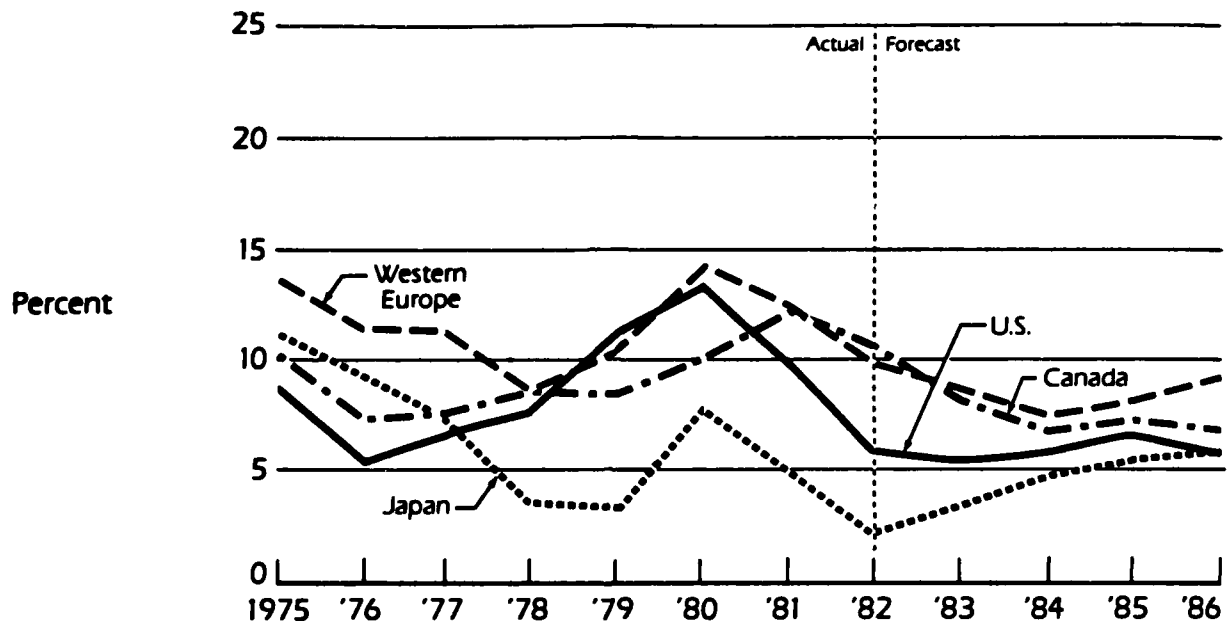


Figure 5-7

Selected West European  
Countries' Inflation Rates (%)

	1982	1986
West Germany	5.2	5.4
U.K.	8.9	7.0
France	11.9	11.0
Italy	16.0	14.7



## World Airline Fuel Consumption Forecast

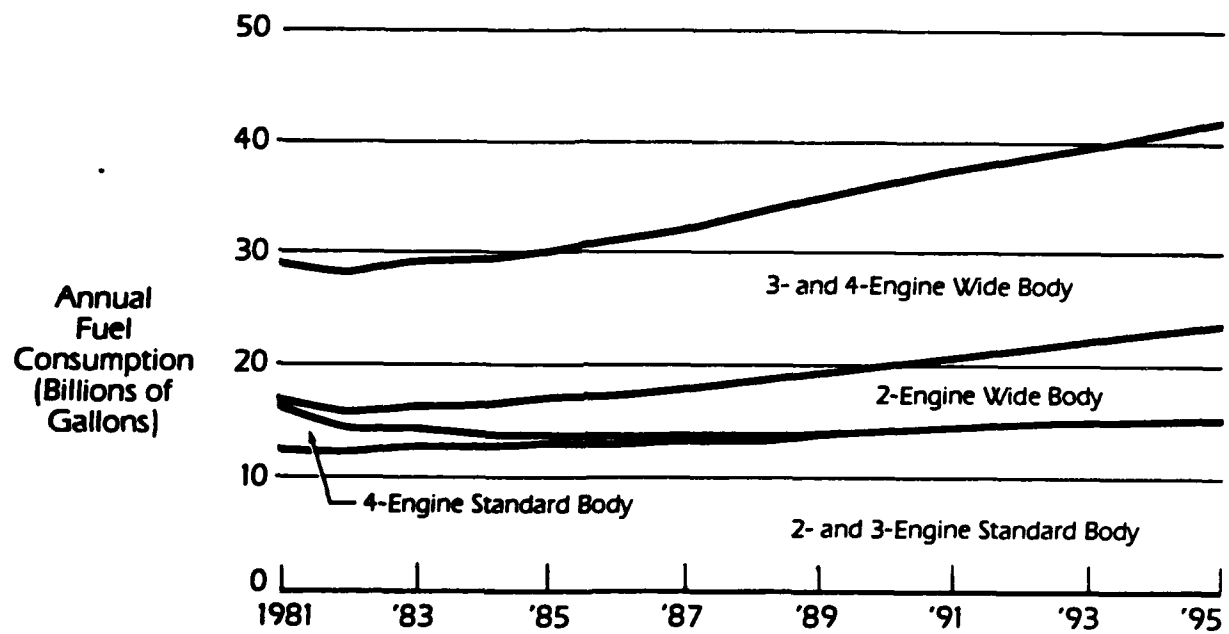


Figure 5-8

## U.S. Airline Fuel Consumption Forecast

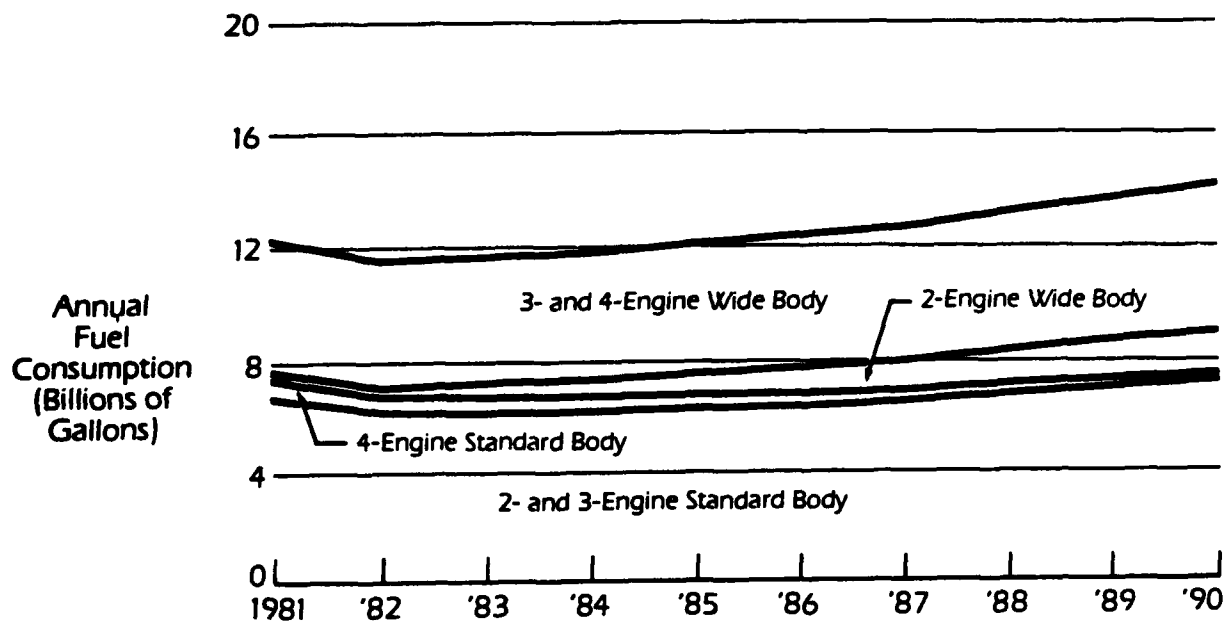


Figure 5-9

## Fuel Consumption Efficiency U.S. Airlines

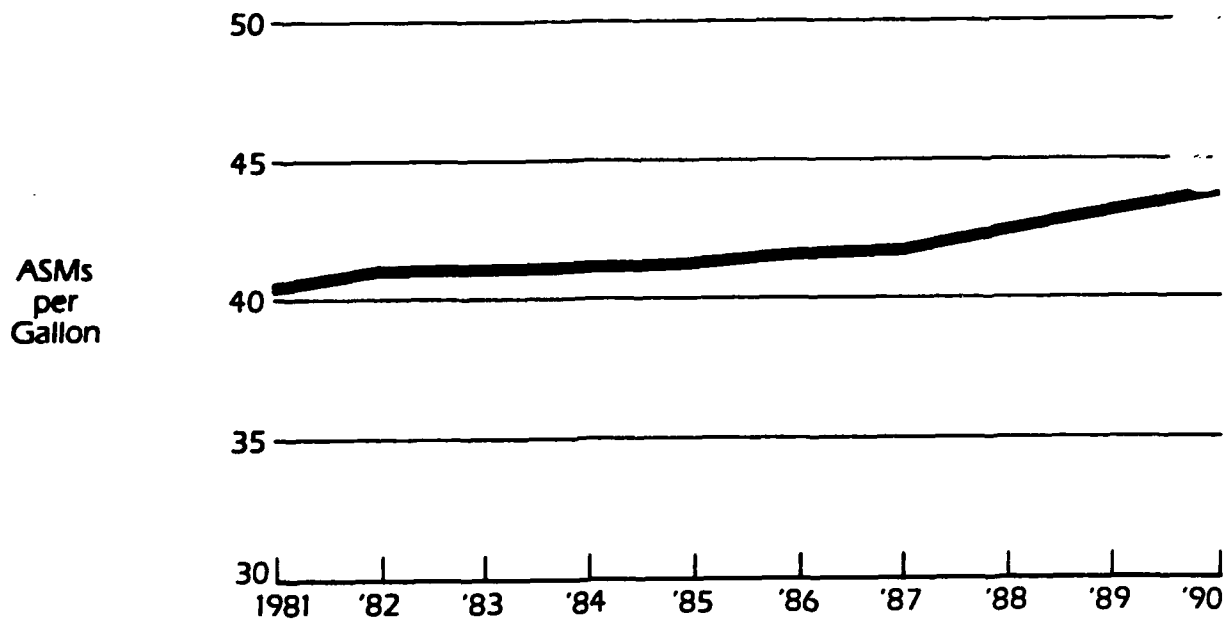


Figure 5-10

## Jet Fuel Cost Forecast U.S. Majors\*—System Operations

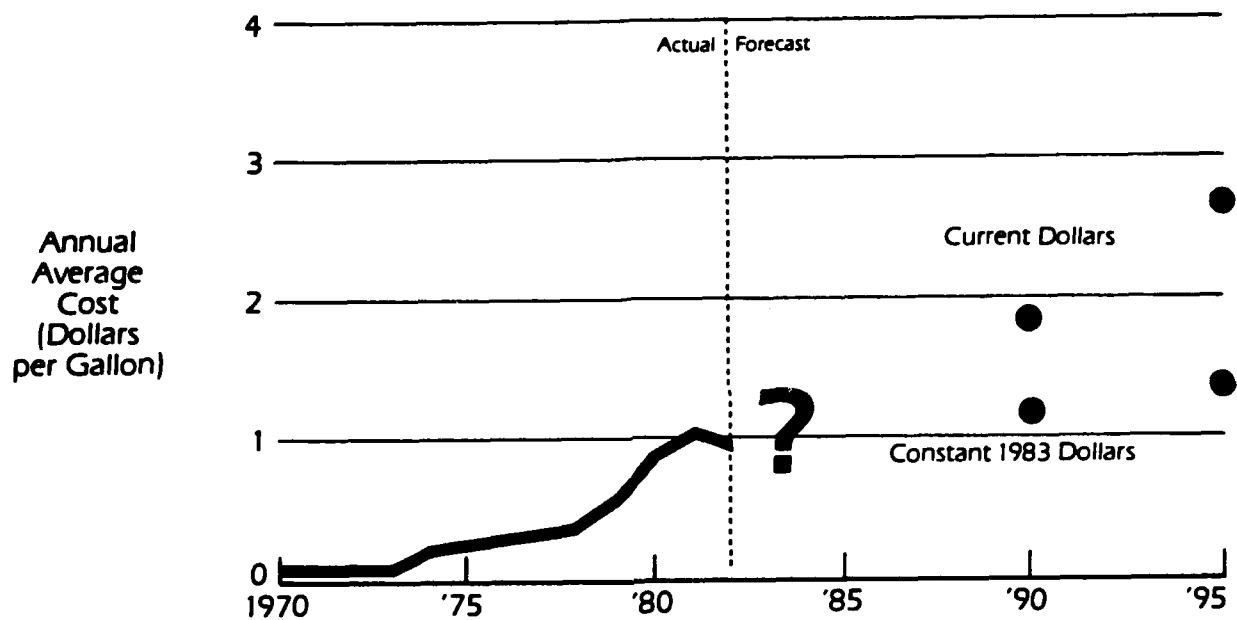


Figure 5-11

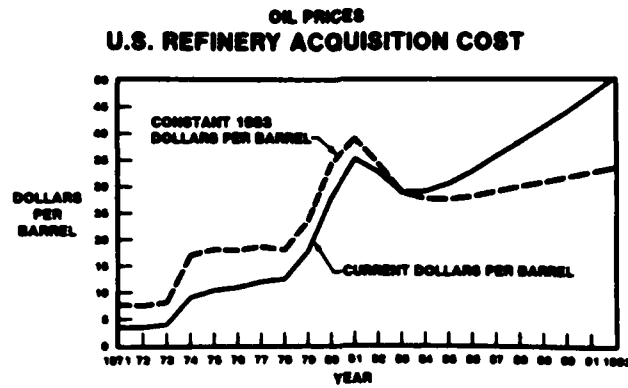


Figure 5-12

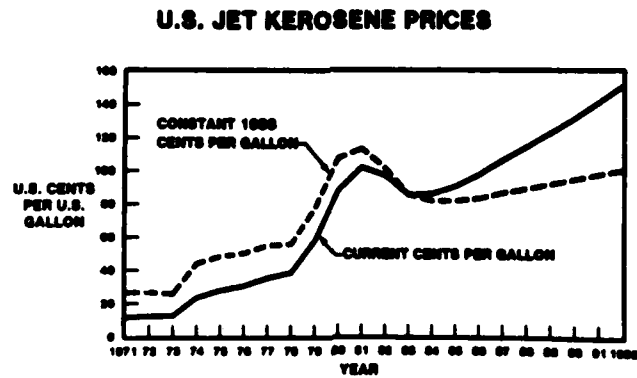


Figure 5-13

## U.S. Demand for Petroleum

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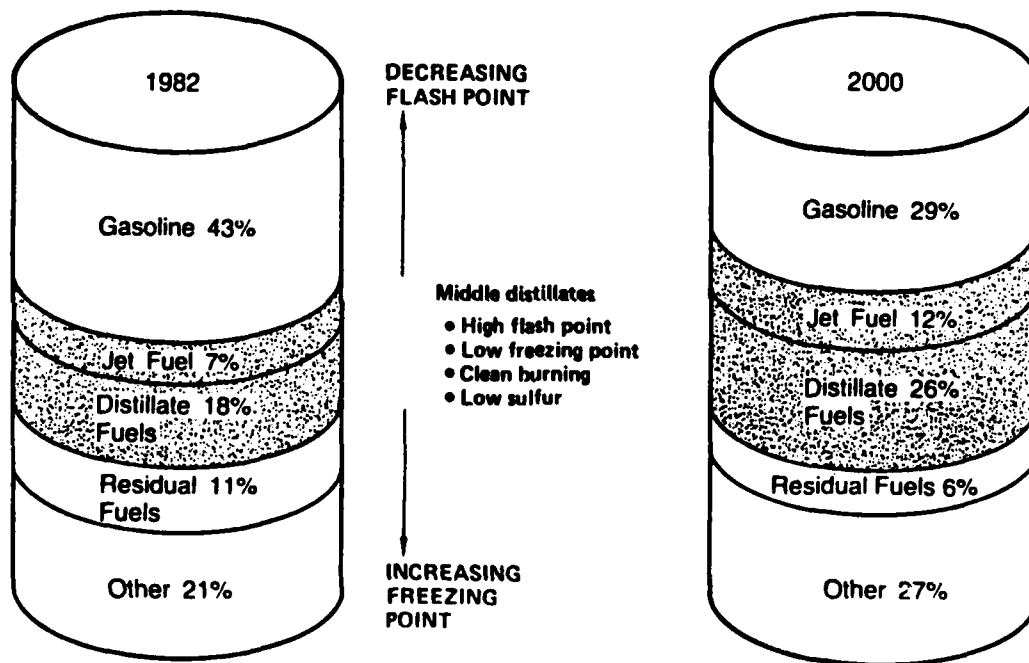


Figure 5-14

## U.S. Jet Fuel Demand

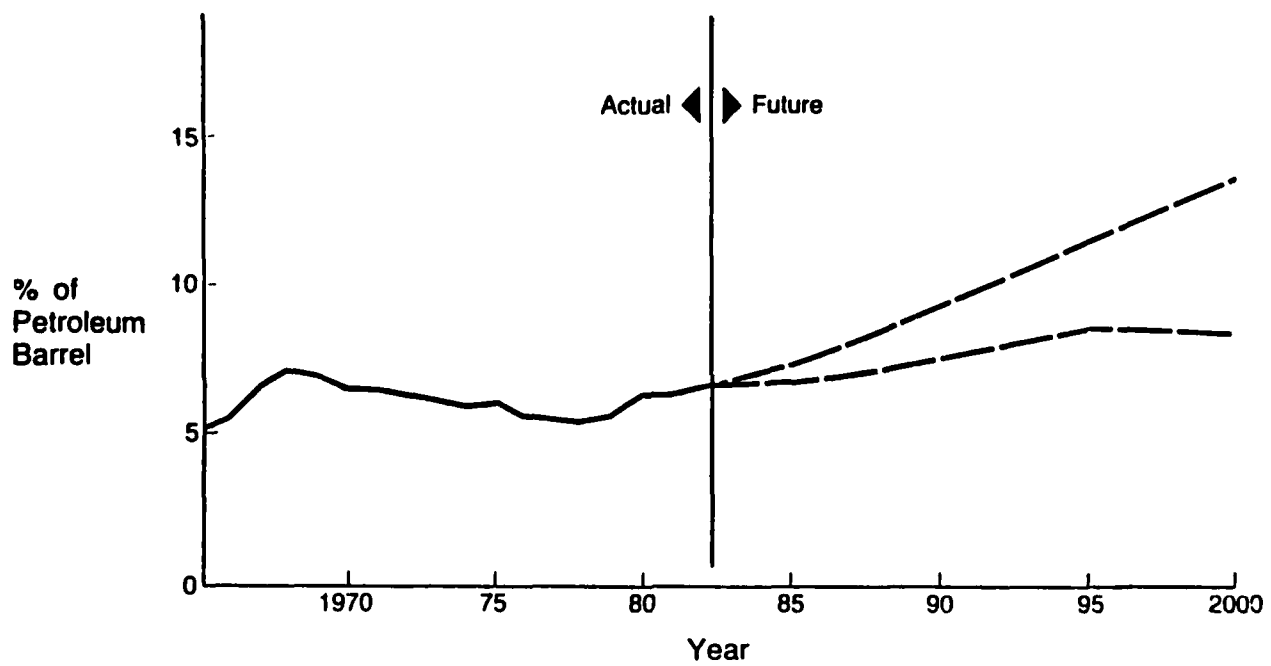


Figure 5-15

## CHAPTER 6

### Natural Gas

#### Why Natural Gas?

As seen in Chapter 1, oil, natural gas, and coal almost split the U.S. energy market into thirds. Natural gas is already a major force in our energy picture but, in the view of this author, it is institutionally restrained from capturing a much larger share. If offered a really free-market opportunity, it is believed that the price of natural gas would be lower, competing with fuels for stationary power, rather than with transportation fuels. As an integral part of this freedom, it is believed that natural gas would become available in much larger quantities (as discussed in Impact) for many decades, affecting the entire world energy market and maintaining lower prices for oil.

The EIA's NEPP-1983 points out that world oil prices should decline until 1985, when oil consumption begins to grow again and create a demand for OPEC oil, exceeding 80% of OPEC production capacity. Part of this pressure seen by EIA comes from rising U.S. prices for gas which, in turn, stimulates industry to switch more from gas usage to oil, and contribute to the demand for OPEC oil. Since NEPP-1983, which was released on October 4, 1983, EIA staff members advise informally that they conclude gas prices will not rise as fast as assumed for NEPP-1983, so that in NEPP-1984, they expect to predict lower gas prices, less switching from gas to oil, less demand for OPEC oil, and consequently lower oil prices at the same reported time period (1985-1990). These forecasts may be seen in Figs. 6-1 and 6-2.

EIA will not start making detailed analyses for NEPP-1984 until January, 1984. The world energy situation and EIA views may change by then, or before NEPP-1984 is released around October next year. But NEPP-1983 shows that the world oil supply/demand balance will be sensitive in 1985-1990, so that fairly small differences in demand could result in appreciable changes in OPEC, and consequently, world oil prices. See Fig. 6-2.

From the material seen to date, it appears that a decrease in internal U.S. natural gas prices by one dollar, will trigger a corresponding drop of four dollars in world oil prices. This may present opportunities that the U.S. (and U.S. aviation) should note well and act upon!

The NEPP-1984 forecast still visualizes gas controlled by the National Gas Policy Act of 1978 (NGPA), but expects its effects on gas prices will be more favorable than assumed in NEPP-1983; however, the ground rules remain the same. It is therefore



contended here that complete deregulation of gas prices and usage, as well as mandating gas pipelines as common carriers (or otherwise releasing natural gas transportation from unnatural restrictions), will further increase gas consumption, gas production, reduce prices, and significantly reduce the price of oil in the world market.

How much? It is difficult to predict prices even under existing institutional conditions. Effects of the changes scheduled under NGPA are now being hotly debated in Congress. Equally eminent analysts predict that gas prices will go up or go down. But, since EIA concludes that a moderate re-evaluation of oil prices downward by about one dollar per thousand cubic feet (million Btu) in NEPP-1984 will probably depress oil prices by \$4/bbl, this author hazards that complete deregulation of gas could realistically depress world oil prices by ten dollars per barrel or more.

At least as far as forecasts and modeling indicate, it appears that this kind of reduction in oil prices would have a long-term effect, depressing oil prices out through the turn of the next century.

This question may turn out to be a moot one. The U.S. may not be able to act soon enough in its natural gas affairs to drive the oil market. Middle East producers are still flaring prodigious quantities of gas, said to be more than twice as many Btus per day than is being produced in oil out of Alaska. Some gas is being reinjected to maintain field pressure, but vast quantities are still being wasted. (There is dispute about whether gas is currently being flared in the U.S. because of inability to market it under the NGPA; apparently some flaring is occurring at small oil wells in Ohio and Indiana.)

Middle East producers plan to use much of their waste gas in producing methanol, as they are able to build the required capital investments for methanol plants from their oil revenues. The most immediate effect from this action may be an impact on our petrochemical market by new Middle East finished products derived from methanol. But both by backing oil out of petrochemicals and by worldwide expansion of methanol uses, this Middle East gas may achieve for Middle East producers much of what the U.S. could gain for itself by unshackling its domestic natural gas production.

While Middle East producers cannot effectively penetrate the U.S. NG market now because of the high costs of transportation by LNG, the same barrier will not exist for methanol. Once produced from natural gas, methanol can be shipped worldwide like crude oil.

These additional methanol profits will also go to the Middle East, the initiatives will remain with them, while U.S. energy imports will not be relieved, and the U.S. will remain as dependent on foreign energy as previously.

If, instead of producing exclusively petrochemicals and methanol, some of the Middle East natural gas is liquefied and a significant world liquid methane network develops, the price of liquid natural gas (LNG) is likely to be substantially lower than prices for aviation gasoline or jet fuel. While this eventually may not be so probable as methanol development, it seems at least possible. If so, it would offer an attractive opportunity for many air carriers, and particularly general aviation piston-driven aircraft, to switch from aviation jet fuel or gasoline to LNG.

If a world-wide LNG distribution system should emerge, so that world LNG prices per Btu could level out substantially lower than petroleum prices, it would very likely justify the design and construction of new aircraft and engines optimized to operate on LNG. These aircraft should not only achieve better performance, maintenance and fuel economy than conventional gasoline - and JetA-powered aircraft, their DOCs should be lower. Some indications of these benefits were discussed in Impact.

So there are several significant reasons why the aviation community should be interested in possible natural gas market developments.

#### Natural Gas Pricing and Taxing

The Impact report discussed various sources for supplying natural gas and indicated their prospects for production. This author concludes, as have many, that present U.S. (and world) natural gas production capacity appreciably exceeds present market demand. The AGA advised that excess gas production capacity is currently about 15% of current U.S. production (AGA advertisement in the The National Journal, October 10, 1983). In this period of a "gas bubble," which is comparable to the "oil glut," there is little incentive to explore for or develop new gas unless it can be sold in some of the high-price categories. Consequently, the national effort to find and produce more gas reserves has been severely curtailed.

Not only has U.S. gas exploration been limited, but technical research and development for extending conventional gas sources and for developing unconventional sources has now languished for many years. Indeed, regulations of the Natural Gas Act of 1938 caught the natural gas industry in its infancy, while the NGPA has not yet released it. Consequently, our U.S. NG technology has never been encouraged nor developed by the drive of genuine economic incentives.

While the DOE has a gas research program as well as a program in basic energy research, while the Institute for Gas Technology and the Gas Research Institute and other institutions can mount impressive presentations of their programs, while the Synthetic Fuels Corporation is promoting some impressive gas production projects, the truth is that there is little enthusiasm or initiative, and very little real effectiveness in the entire U.S. gas R&D picture. Some individual efforts are very good, but there

is no broad drive, as there has been in electronics and other fields. This same apathy exists in enhanced oil recovery (EOR) in the U.S. for different, but parallel reasons. How can real enthusiasm develop when thousands of oil wells and gas wells are capped in the U.S. because of regulations, where new, speculative drilling is financially more profitable than producing existing, shut-in gas resources, where the capital investments have already been made? When institutional and tax barriers strangle a market, technological initiative is also strangled.

Some observers have taken this soft supply of reserves as an indication that U.S. gas resources must be very limited. The Impact report and most industry sources contend this is not the case. In fact, some feel that the world's natural gas resources may be either practically or literally unlimited. This author concludes that, given free market conditions, the world's and the U.S.'s gas supplies are vast indeed.

And this author also concludes that the technological problems of natural gas exploration, production and consumption are far transcended by its institutional and pricing problems. Consequently, while the Impact report was more concerned with the size of our gas resource and its potential production, this report is concerned more with the institutional restrictions which prevent natural gas from realizing its potential in the U.S. and, in turn, the world energy market.

NEPP-1983, which was presented to Congress on October 4, 1983, lists two initiatives which DOE Secretary Hodel characterizes as, "vital:" the removal of controls on natural gas wellhead prices, and reform of nuclear licensing and regulatory processes.

#### Natural Gas Regulation

Natural gas regulation in the United States began with the Natural Gas Act of 1938, which assigned to the Federal Power Commission, authority to regulate gas prices, sale conditions, and the rate of return earned by interstate pipelines. The last two words in that sentence are important: FPC regulation applied only to interstate gas and only to that transported in pipelines. Intrastate gas remained unregulated, placing further competitive stresses and distortions on interstate operations.

While imported natural gas is also regulated when it enters the U.S. interstate pipeline system, both imported and domestic gas which is transported in the U.S. independent of the interstate pipeline distribution system, is unregulated. If expanded to compete with the pipelines, an unregulated national LNG distribution system would challenge the regulated system, as well as the special buyer/seller relationships inherent in the present pipeline system. Natural gas converted to methanol, transported unregulated as a liquid, and reconverted to methane, would also escape the interstate gas control, tax and contract structure.

It was confirmed by the Supreme Court's 1954 Phillips Case that the Natural Gas Act empowers FPC to regulate natural gas prices at the wellhead. Consequently, FPC decided to regulate prices of individual producers based on their historic rates of return. When this procedure proved too cumbersome, FPC based prices on the historic costs of seven major gas producing areas in the U.S., established by a series of rate proceedings, which were revised from time to time. These area rates were finally replaced in December 1973 with a blanket escalation rate.

This interstate regulation led to a gradual shift of production toward the unregulated intrastate market and, by 1972, shortages were beginning to show up in the interstate market. In 1973, priorities were established for nine different categories of interstate users and the 1977 Emergency Natural Gas Act gave the President authority to transfer natural gas from surplus areas to shortage areas.

The NPGA of 1978 required the Federal Energy Regulatory Commission (FERC, which succeeded the FPC) to regulate intrastate gas as well as interstate gas and a set of prices was established according to the physical description of each well, the year it was drilled, and whether its production was dedicated to interstate commerce by contract. A set of incremental pricing rules was established to allocate the cost of some high-priced gas to certain industrial users, thereby supplying residences with more of the low-cost gas.

In 1979 the Act was amended to protect natural gas to "essential agriculture" and other "high priority" users, while deregulating gas produced from deep wells, coal seams, and Devonian Shale. This provision prohibited new electrical generation plants from using natural gas, and imposed other industrial restrictions. In 1980, the Act was extended by setting a price for new tight formation gas. For those interested, DOE/EIA-0329, A Chronology of Major Oil and Gas Regulations, February 1982, lists and describes, by year, all significant oil and gas regulations from 1889 to 1982.

A table showing the categories of natural gas and its "deregulation" schedule under the NGPA of 1978 has been compiled by the American Gas Association (AGA) and is included here as Fig. 6-3. Note that all its prices were based on crude oil prices before they doubled in 1979-80. In less than a year after their establishment, these regulated prices were therefore no longer comparable to oil prices. If for no other reason, The NGPA deserves revision or repeal because of its obsolete and unrealistic price basis.

Note also that final deregulation under the Act is scheduled for July 1, 1987. But, at that time, more categories of gas will remain regulated than will have been deregulated. In fact, all "old gas", or 40% of the proven natural gas resource in the United States, will remain regulated until it is finally exhausted. But how will this old gas be sold when its price is required to be held so far below fair market price? Notice in the Chart (Fig. 6-3) that, under Natural Gas Dedicated to Interstate Commerce (Sec. 104), "Minimum rate gas," which was held to \$0.182/Mcf in April

1977, will be allowed to rise to only \$0.316/Mcf in 1985. Why would a producer sell any of this gas at the regulated price when "tight formation gas" is allowed a price of \$6.140/Mcf, almost 20 times as great, while new offshore gas, rollover contract gas, and other categories are completely deregulated?

Under the NGPA, in 1985 when all gas is popularly believed to have been deregulated, this "minimum rate gas," at \$0.316/Mcf, is still regulated at a level equal to crude oil at \$1.85 per barrel!

Clearly the NGPA of 1978 is a half-way measure. It was recognized as a compromise at its time of passage; while it anticipated inflation, it did not allow for another general increase in oil prices, and its popular reputation for "deregulating" gas in 1985 is sadly misleading. Under this present legislation, U.S. natural gas will never be deregulated to the same extent as crude oil in the United States. There is general agreement that something must be done. Depending on their interests, various constituents are recommending different solutions.

#### Opinions on U.S. Natural Gas

The U.S. natural gas situation is complicated enough so that it can be easily misinterpreted and confused by every analyst or spokesman with a vested interest. Like the Bible, references and examples can be cited to prove almost anything one wishes. It is difficult for those without occupational or investment bias to remain unopinionated; in fact, probably everyone interested in the subject inevitably develops strong opinions. While attempting to remain objective, thus author is conscious of having strong, perhaps radical, opinions.

It is probably fair to say that the present U.S. natural gas situation and the NGPA victimize all U.S. participants in the natural gas arena to some extent. In turn, the entire U.S. public is victimized by higher prices. Through effects on world oil prices and markets, the entire world and its population are affected. Even the most primitive people are affected when their forests are depleted directly or indirectly because of the world energy situation. For all those who suffer losses, there must be others who benefit. In the opinion of this author, the greatest benefit accrues now to OPEC and other oil producers, through OPEC maintenance of higher world oil prices. The U.S. and its public therefore suffer by further subsidy of OPEC; even more suffering is borne by the financially beleaguered nations.

But, rather than promoting opinions which this author

considers logical and fair, an attempt will be made here to present representative opinions, while references will be cited for further study. Obviously conflicting views will be quoted, and some complete contradictions may be noted. Somebody has to be wrong. Who? If the material is presented here successfully, a reader may develop his own opinion, which well may be different from this author's.

### Resources for the Future

We must expect any organization to support its "best interest", regardless of the "common good." The Soviet TV commentator who recently editorialized that his government erred in shooting down KAL Flight 007, is unlikely to continue broadcasting his nonconforming view.

Since science has not successfully penetrated private thoughts, we cannot be sure whether any independent organization or independent scholar is free from all bias. Certainly every individual must harbor opinions which are affected by his political views. But, lacking evidence to the contrary, the views of Dr. Milton Russell, Director of the Center for Energy Policy Research, Resources for the Future (RFF), are presented here as probably neutral. Some of his thoughts are extracted from, "The Natural Gas Price Puzzle," Resources, February 1983, RFF:

Today's natural gas situation began with the 1954 Phillips Decision that imposed price controls on interstate gas. It took almost a decade to work out reaction to this decision but, by the mid-1960s, underpriced gas was being consumed faster than it was being found. Low prices caused consumers to install more gas equipment than could be served at those low prices and gas became "scarce". Then the Government imposed use restrictions on industry, to protect home owners. This forced many former industrial users out of the gas market.

The situation demanded relief and, after much struggle, the Natural Gas Policy Act of 1978 was passed. Though acknowledged incomplete, it began some relief from price restrictions, shifted gas to areas in short supply, transferred costs from homeowners to industrial users, and permitted some price increases where more gas supply was expected to develop.

But the NGPA permitted greater increase in average gas prices than its framers intended, and the price gap between gas and liquid fuels started closing quickly. While the NGPA provided escalation for inflation, its price schedule was referenced to the then current world price of oil, and has since retained that price basis. In less than a year after passage of the NGPA, oil prices doubled again. This stimulated the price of uncontrolled gas categories to rise much higher than expected. Gas prices may still rise somewhat more to close the gap but, after rapid rises in the past few years, "Evidence suggests that, on the basis of

supply and demand fundamentals, prices will stabilize this year (1983) or next--barring further disruptions in oil markets."

While gas consumers are complaining of high prices and expecting additional price rises, some producers complain that they cannot find markets for their gas. How can this be?

Although the glut exists, it is a short-run surplus, with gas produced from existing wells, and not based on long-run growth in production capability. Under the NGPA, there is little incentive for additional exploration and development, except in the uncontrolled, high-priced gas categories. The 1979 rapid rise in oil prices led early to more drilling in established fields, not to exploration for new finds.

Before the gas glut became apparent, pipelines had bid up prices from suppliers in order to assure themselves long-term supplies. They also agreed to take-or-pay provisions, permitting producers to deliver their highest-priced gas, assuring producers of high revenue and earlier payouts on their investments. Pipelines therefore lost their ability to decrease these high-priced purchases when the recession, tougher competition from oil, and increased conservation, shrank the gas market demand.

Much gas is now controlled at prices lower than can pay for its replacement by new exploration and development. At the same time, some unregulated gas has been contracted at very high prices. Natural gas is being imported from Canada and Mexico at about double the domestic price, and a small quantity of LNG is imported from Algeria at even higher prices. These prices are all passed through and raise the cost to customers. So, as demand subsides due to high prices, the lower-priced, regulated, gas is withdrawn from the market and the average price is pushed even higher. Long-term, take-or-pay contracts assure that this high-priced gas continues to be delivered; its price is not lowered due to decreased demand.

The gas market is necessarily composed of long-term commitments: pipeline investments, stationary customers with large boilers and plants and, in the case of LNG, refrigeration plants, cryogenic shipping terminals, and specialized ships. All these capital investments need long-term, stable returns. The gas market therefore cannot respond rapidly to a drop in demand. Similarly, exploration and development for new gas require long-term commitment of substantial investments. Unlike oil which can be shipped anywhere, gas is essentially tied to the pipeline system and existing contracts; its markets are inflexible.

The price to customers is increased by take-or-pay contracts as described above, but also further by inflation, higher interest rates, and fixed costs spread over the smaller quantity purchased.

Although this explanation of today's situation is fairly

straightforward, as Russell points out, it is "---vastly more complicated when specific producers, pipelines, distributors, and customers are considered. The average cost of gas as it enters a particular pipeline, for example, depends on historical accident, location, timing, and bargaining power. Management decisions turn out well in some cases and poorly in others, and sometimes may favor pipeline interests even when that means higher prices down the line. As to individual customers, their rates may depend on who serves them, which customers share their system, and the goals and skills of state regulators who monitor distributor costs and rate structures."

"Legislation can shift costs among parties, by altering contract terms and limiting take requirements, for example, but laws cannot make costs go away...Because of the importance of natural gas and the strong emotions it arouses, the coming debate is likely to be great political theater."

This completes The digest of Russell's comments in February, 1983.

#### Proposed DOE Legislation

Natural gas legislation proposed by the Administration is likely to be changed before passage by Congress. But, since any bill passed may contain elements of DOE's recommendations, the gist of its proposal are given here:

DOE identifies its basic provisions as:

- o Deregualtion of all gas by a certain date.
- o Contract Adjustments
  - Renegotiation incentive
  - Take or pay
  - Indefinite escalators
- o Consumer Protection Element

And summarizes its provisions as follows:

- o Consumer protection through elimination of automatic pass through of price increases by pipelines.
  - Gas price increases above inflation may not be passed through automatically by pipelines.
  - Process requires full public proceeding with appropriate standards.
  - Ceiling price for most gas becomes lesser of NGPA price or "average" new free market price. ("gas cap").



- Indefinite price escalators limited by "gas cap".
- o Free the parties to negotiate new contracts with incentives to do so at low prices.
- All new and renegotiated contracts deregulated.
- Either party may market-out on any contract not negotiated by 1/1/85.
- o Eliminate disincentives for use of low cost gas.
- Increase competition through contract carriage at incentive rates.
- Take-or-pay contracts may be reduced to 70% by purchaser.
- Eliminate Fuel Use Act and incremental pricing.

There are other special provisions proposed, such as: contracts that have not been renegotiated may be cancelled by either party; controls cannot be reimposed by the President or Congress; FERC can require a pipeline with available capacity to carry gas under contract between a producer and a purchaser at an incentive rate; no pipeline can take gas at a higher rate than its rate for any less expensive gas; a ceiling is placed on deep gas, which is currently deregulated.

#### Nolan Ezra Clark and Glenn Willett Clark - Contract Carriage

As reported by The Wall Street Journal of May 4, 1983, "The Clark brothers are Washington, D.C. lawyers and authors of a forthcoming policy study on natural gas." In that issue of the Journal appears their editorial, "The Way to Deregulate Natural Gas."

From a philosophical view, it is well worthwhile considering the opening statement of the Clarks, "Drafters of the Department of Energy's natural-gas 'decontrol' bill should be reminded of George Washington's counsel: 'If, to please the people, we offer what we ourselves disapprove, how can we afterward defend our work? Let us raise a standard to which the wise and honest can repair...'" Some may feel that Washington's statement is not appropriate to the DOE's proposed natural gas legislation. But few will say that it does not apply well to the Natural Gas Act of 1938, the Phillips Decision of 1954, the NGPA of 1978, and the contorted natural-gas situation which now strangles United States energy.

The Clarks offer some philosophy of their own which is also incisive: "An economy is to some degree impoverished if any price is maintained, by cartel or commission, at a level higher or

lower than that established by competitive marginal cost pricing."

They continue, "The extreme ease of entry into the production of natural gas ensures that producers can never pose an impediment to the marginal-cost pricing. On this score the Supreme Court's 1954 Phillips decision was wrong. High fixed costs of pipeline construction and government-imposed barriers to movement of natural gas could, however, pose just such an impediment. The principal solution is to provide open access to natural gas transportation facilities--to mandate contract carriage. The concept of contract carriage is simple. Natural gas transporters could be required to carry gas for others on a space-available basis."

"...(DOE) proposes to require contract carriage subject, however to prior federal approval. This would inhibit the entry of new natural gas merchants. If new merchants aren't encouraged, we doubt that a truly competitive market system for natural gas will emerge."

"Another DOE 'consumer protection' measure is to give federal agency increased power to regulate prices charged by pipelines. This is a step backward. Failure to achieve comprehensive deregulation will perpetuate a constant pressure to thrust regulation back upstream to the wellhead level. The Phillips decision can be made to live again."

"In addition, retaining some wellhead price regulation for two years, as proposed, perpetuates the vice of price averaging. This forecloses the discovery and use of a market-clearing wellhead price. Since prices for some categories--'old' gas--would be held artificially low, prices of other categories would be artificially high. This categorization of gas as 'old,' 'new,' 'deep,' or any other permutation thereof is arbitrary and economically fallacious. Natural gas is a fungible commodity. Transportation costs aside, all gas should command the same price from any producer. (Emphasis added) In the most competitive markets, such as those for corn and wheat, that is the result."

"The DOE plan contemplates that producers and pipelines seeking to renegotiate contracts must arrive at fixed prices, rather than use flex-price contracts. This prevents the price changes needed to adjust supply to demand."

"...The beneficiaries of a postponed transition to a free market,...will be two classes of businesses that have reaped extraordinary profits in the past from government regulation of natural gas: (a) pipelines with large 'old' gas cushions--which are privileged to buy for less--and (b) producers of 'new,' 'deep,' or 'foreign' gas--which are privileged to sell for more. In both cases, the beneficiaries are simply exploiting a historic, government-created, non-market-clearing price."

### American Gas Association

The AGA does not favor accelerated decontrol of gas prices in advance of the NGPA. They believe rapid decontrol will bring higher prices and reduce consumption of an already severely curtailed market. Demand is already constrained below existing U.S. production capacity and further price increases will only shrink an already artificially constrained market.

As the representative largely of U.S. gas transporters--the pipelines--AGA does not favor involuntary contract carriage of natural gas.

AGA's views are briefly presented by a two-page advertisement in The National Journal of October 10, 1983, authored by George H. Lawrence, President, AGA. Its highlights are as follows:

"The short-term gas supply outlook shows an excess gas capacity representing approximately 15 per cent of current production. Given the size of this present excess, some three trillion cubic feet (Tcf) per year of domestic gas and the availability of at least one Tcf of additional Canadian gas, the near-term outlook is excellent."

"As for the long-term, the outlook is also much improved. The American Gas Association's (AGA) Gas Supply Committee has projected that supplies from lower-48 states reservoirs can be stabilized through the year 2000 at about current levels and can be supplemented by gas from Canada, Mexico, coal gas, Alaska, liquefied natural gas, and new technologies."

"Federal government data show that, in 1981, gas reserve additions in the lower-48 states exceeded production for the first time in 14 years, and in 1982 gas reserve additions were roughly equal to production...AGA projections forecast that prices during the next five years will increase much more slowly at the burner-tip than during the 1977-1982 period...Indeed, on a national average basis, gas prices have begun to decline--significantly in some regions of the country."

There will be, "---pressure for lower gas prices for the rest of 1983. Actually, one of the few positive benefits of the divisive gas pricing debate over the past two years has been the virtual consensus that the market clearing price for natural gas at the wellhead is not crude oil parity, but rather a price which enables gas to compete in the industrial market with residual crude."

"...AGA's position on old gas is well known--that the very small supply response of across-the-board decontrol does not justify the consumer price impact...That is why AGA's longstanding and aggressive support for effective decontrol has been limited to new gas...decontrol of new gas prices is critical and essential."

"... Capacity, storage, priority and timing of service to hundreds of distribution points on each pipeline system, and other transportation-related decisions cannot be made in Washington..."

"Mandatory carriage is supposed to be equitable because system and mandatory transportation customers would get the same treatment... Mandatory carriage is supposed to increase industrial demand, fill the pipeline system, and reduce overall rates by spreading fixed costs...Mandatory carriage would be a reversal of the trend toward deregulation of other industries...The voluntary programs encouraged by the FERC are just now becoming effective. Interstate pipelines already transport large amounts of natural gas for independent shippers under voluntary contract carriage arrangements..."

"The nation's natural gas consumers need and deserve legislative relief this winter that is now blocked by lack of consensus on the issues of old gas and mandatory carriage. It is time for the Congress to move boldly and take advantage of the opportunity to create a new energy era by making it possible for natural gas to make a larger contribution to a revitalized national economy."

#### Richard J. Gonzales

Based on a presentation made to Producers & Investors, Inc. seminar, "Strategy for Natural Gas Deregulation," in Houston, Feb. 26, 1983, a four-page editorial by Consulting Economist Richard J. Gonzales of Houston, "Natural Gas Policy Act Modification can Bring Correct Market Prices," was printed in The Oil and Gas Journal, April 5, 1983.

Gonzales points out some enormous costs imposed by federal government control of natural gas prices and usage: In 1981 the U.S. would have used 750 million tons more of coal and offset 1.4 billion barrels of oil and 10 Tcf of natural gas; the savings to customers would have been about \$60 billion. Crude oil prices would be far below that set by OPEC; the total savings to U.S. energy consumers would have been, "...in excess of \$100 billion a year currently."

He discusses the Natural Gas Act, the Phillips Decision and the consequences of low gas prices. Although President Eisenhower appointed an Advisory Cabinet Committee on Energy in July 1954, which recommended that the government should not regulate the price of natural gas prior to its entry into an interstate pipeline (also that oil imports be limited and that coal use be exploited), none of the committee's recommendations were effectively implemented. In some markets gas was cheaper than coal, despite its inherent advantages.

"The tripling of foreign oil prices to more than \$10/bbl in 1974 should have brought about an immediate change in U.S. energy policies to encourage more rapid development of abundant domestic energy resources, including coal. Instead, U.S. oil and gas

prices were kept under controls at levels far below the cost of foreign supplies." OPEC concluded we considered the price of oil cheap, and raised their prices.

"The need for changes in U.S. energy policies had become obvious by 1977. The correct and simple solution would have been removal of price controls on crude oil and natural gas. Such action would have started a sharp surge in drilling that would have reduced the doubling of prices by OPEC in 1979." Instead, when President Carter proposed a synthetic fuel program, "...subsidized until prices reached \$28/bbl, OPEC concluded that it could safely raise prices to or above that level, as it would take years to complete synthetic fuel plants."

When these higher prices caused a sharp increase of oil company profits, Congress imposed the "Windfall Profits Tax" on domestic crude oil. "This is not a tax on profits but on the gross margin between selling prices and arbitrary lower levels set without any economic justification. Congress was unwilling to tax imports on the assumption that such action would be costly to consumers. It did not hesitate to levy taxes on domestic production, which added to all other taxes an additional 20 cents/gal of crude oil produced by major oil companies in 1981."

On the NGPA of 1978, Gonzalez comments, "This act complicated regulation by creating more than 20 different categories of gas with varying prices and by mandating actions as to gas use and allocation of increases in prices contrary to the working of a competitive market. Congress assumed erroneously that such action would protect consumers, especially those using gas for home heating." He especially deplores extension of federal regulation to the intrastate market.

"Congress recognized in NGPA that prices set by regulation should be just and reasonable but violated that principle by specifying different prices for different categories of producers...Congress made a mistake in setting arbitrary price levels in NGPA for different categories of gas. It should have removed controls in 1978 to allow the market to establish fair value for gas in relation to coal, heating oil, and electricity." If Congress was attempting to protect consumers from a price shock, it should have devised a transition schedule which would not have produced a later shock. But the NGPA assumed a firm \$15/bbl for the price of oil, which more than doubled shortly thereafter.

Two major defects of NGPA are that it continues regulation of a large volume of old gas (about 40% U.S. reserves-Ed.) beyond 1985, while it removes price controls from new gas mostly from very deep wells. Competition for the limited supply of unregulated gas, "...caused bids for the limited supply of deep gas to exceed \$9/Mcf, some three to six times the level of regulated prices and almost twice prices paid for gas imported from Canada and Mexico."

"Failure to encourage development of all new gas has limited outlook for new supplies so seriously that consideration is being given to movement of gas from the North Slope of Alaska to the lower 48 states. The anticipated cost of this gas delivered to the Canadian border will exceed \$15/Mcf." By bargaining processes, "...about \$5/Mcf would be reasonable for U.S. natural gas. An increase to that level would bring about a sharp rise in drilling of gas wells and in the development of new gas supplies. The influence of higher prices on supplies and on conservation should work to limit further price increases for both natural gas and crude oil."

Gonzales discusses how gas prices should relate to the price of coal, considering the transportation, handling, environmental and other costs of using coal. He concludes that, "...the reasonable competitive value of natural gas is higher than the regulated gas prices set by NGPA but less than prices being paid for deep gas."

"Continuation of present underpricing of natural gas is not in the public interest because it gives incorrect signals to consumers and producers, delaying the shift to much greater use of coal. Consumers will be served best by prompt action to raise gas prices to their market value on or before 1985."

He points out how a windfall profits tax proposed for natural gas is a fallacy. We should have learned from both our tax and production lessons in regulating oil. Gas development is greatly lagging oil development (even with the WPT on oil - Ed.).

"...the U.S. has experienced enormous unnecessary costs because of policies that kept prices of natural gas and oil below their fair market value relative to coal. Delay in correcting these policies increases long-run costs to consumers and hurts the national economy... The choice remains whether to deregulate gas now or to phase control for complete deregulation by 1985. Either is better than allowing the NGPA to remain in effect without change."

"It is harmful to focus attention on the various objections to correct the mistakes that have been made in energy policies. Experience with decontrol of crude oil prices indicates that such action is feasible and may help limit or even reduce the price of foreign and domestic supplies. The time has come to work on achieving the consensus necessary to modify the Natural Gas Policy Act in the near future to make sure that gas prices move to their correct level on or before January 1985."

#### U.S. Natural Gas Resources

This author attaches little significance and invests little confidence in estimates of the U.S. natural gas reserve, discovered and undiscovered. Since oil price deregulation, we have already

seen that higher oil prices stimulate discovery even though the Windfall Profits Tax still favors foreign exploration in preference to domestic production. The U.S. natural gas market has never been deregulated during any of its mature history. It therefore seems absurd to estimate our potential gas reserves on the basis of information which has not only failed to stimulate production, but has severely retarded the whole industry.

The rate at which U.S. natural gas can be produced is somewhat more tangible, because it is limited by the number of wells drilled, their production rate, the rate at which new wells might be drilled, etc. Nevertheless, knowing we are in a severely depressed development climate today, while acknowledging that the history of natural gas has never stimulated its potential, how can we project our production limit five or ten years from now?

Forecasting U.S. natural gas is almost like forecasting U.S. potential for producing shale oil, knowing that we have a larger shale oil resource than the entire Middle East has oil resources. As long as the cost of producing oil from that shale is appreciably higher than the price of crude oil (including imported crude), our shale production potential will remain nearly zero. The difference is that while shale oil prices are set by the technological and industrial tasks, gas prices have been set by legislation. But the effect is the same, both our present gas production and the outlook for future gas production have not only been stunted by these policies, they have been entirely shaped by these policies. In the opinion of this author, the U.S. has no reasonable basis for estimating its potential gas resources. All reasonable estimates of U.S. gas supplies are therefore inherently and necessarily conservative.

Nevertheless, as has been noted before, it is in our nature to forecast. If for no other reason, budgets inflict the process on us. (Perhaps that is why our budgetary plans are often unrealistic.)

#### OTA

The Congressional Office of Technology Assessment (OTA) has published U.S. Natural Gas Availability, September, 1983. In this report, OTA also discusses the vicissitudes of forecasting, as most forecasts should, but identifies the uncertainties as technical, rather than institutional. Perhaps that is the diplomatic course for a technical study group which reports to and exists at the pleasure of an institutional organization like the U.S. Congress.

OTA comments, "Within the last 5 years or so, the general perception about the outlook for future U.S. gas supplies has moved from pessimism to considerable optimism. The pessimism was based partly on short-term problems, such as periodic regional shortages, and partly on disturbing long-term trends, such as the declining finding rate for new gas fields and, since the late 1960s, the ominous and apparently unstoppable decline of proved reserves. The new optimism is based on several factors, including the gas 'bubble' caused by declining gas demand coupled with high gas deliverability, the rebound of reserve additions to levels which exceed production in 1978 and 1981, and continuing

optimistic estimates of domestic gas resources by the U.S. Geological Survey (USGS) and the industry-based Potential Gas Committee (PGC)."

"What does this apparent change in the outlook for U.S. natural gas supply mean? Can we now count on natural gas to play a major, perhaps even expanded role in satisfying U.S. energy requirements, or is the seeming turnabout only a temporary respite from a continuing decline in gas reserve levels and, soon to follow, a decline in gas production capabilities?"

"Certain technical uncertainties--primarily those associated with incomplete geological understanding, alternative interpretations of past discovery trends, and difficulties in projecting likely patterns of future gas discoveries--are so substantial that by themselves they prevent a reliable estimation of the remaining recoverable gas resource and the likely year 2000 production rate. Even after ignoring the potential for significant changes in gas prices and technology in the future, OTA could not narrow its range of estimates of resources and future production beyond a factor of 2 from the lowest to the highest estimate. Inclusion of uncertainties associated with changing gas prices and market demand and the continuing evolution of gas exploration and production technology would undoubtedly widen the range still further."

"OTA finds no convincing basis for the common argument that the area of the Lower 48 States is so well known that there is a substantial consensus on the magnitude of the gas resource base." There are several substantive issues that remain unresolved in estimating the present gas resource base: use of past discovery trends, the potential of small fields, new gas from old fields, frontier areas including deep gas, and stratigraphic gas traps.

"In addition to these five issues, a level of uncertainty is ever present in the process of estimating the quantity of a resource that cannot be measured directly prior to its actual production."

Then OTA notes uncertainties in interpretation and extrapolation of past discovery trends: inadequate discovery indicators, uncertainty about the future growth of new fields, and difficulties in interpreting the recent surge in reserve additions.

Lastly, OTA discusses the uncertainty of production from proved reserves--the R/P ratio. This author sees a parallel to the E/GNP ratio in various national economies, including that of the U.S., as well as in the more recent revision in the MIR, minimum industrial reserve of oil needed to maintain refining operations. E/GNPs have been drastically re-evaluated, while the previously inviolable MIR is currently being re-established by the National Petroleum Council.

In the past, forecasts were confidently based on these ratios,



which were presumed to hold constant. Now we have changed some of these bedrock indexes, are revising others, and appropriately are challenging many of the remaining. The R/P ratio deserves thorough re-evaluation but how can we establish a new R/P until we have the effects of new gas pricing policies, or at least have some idea of what those policies will be?

Noting these qualifiers, OTA concludes that in year 2000 U.S. resources may lie between 400 and 900 Tcf, and that production could run between 9 Tcf/yr and 19 Tcf/yr (U.S. production in 1982 was 20 Tcf-Ed.).

#### Potential Gas Committee

In its March 7, 1983 issue, The Oil and Gas Journal includes two articles which discuss U.S. potential gas resources, and the supply outlook in 1990.

The first article, "Estimate of U.S. Potential Gas Resources Cut," reports on the latest estimate from the Potential Gas Agency (PGA) at the Colorado School of Mines, which staffs the agency's 143 member Potential Gas Committee (PGC). The PGC estimates that about 876 trillion cubic feet of gas remains to be discovered onshore and offshore both in the Lower 48 and in Alaska.

Although it may be misleading to consider reserves in terms of years, at today's annual consumption rate, the PGC Estimate would supply the U.S. with gas for over 40 years. (This author would hope that our consumption rate will be able to increase from 20 Tcf/yr to 30 Tcf/yr and that, by the same market stimulation, our undiscovered reserves will be found to be still larger. From this unbridled optimist, a natural gas future of 50 years or more is envisioned at production rates 150-200% that of 1983).

The PGA report notes that its estimate has decreased by 37 Tcf from year end 1981, which is about equal to the U.S. proved reserves during the past two years. J.C. Herrington, the committee chairman, is quoted, "This means there has been no significant new information developed during the past 2 years that would have caused the committee to alter substantially its previous concept of the potential supply. Results of exploration and drilling during the past two years have reinforced the committee's position that more than half of the resource originally existing in this country remains to be found and more that 60% remains to be produced."

The second article, "U.S. Facing Natural Gas Shortfall in 1990s," comments, "The U.S. faces a shortfall of natural gas by the early 1990s."

"That's because it lacks sound policies to deal with current gas market problems, thus derailing the gas industry's plans to develop the required new supplies," the article quotes from Lloyd Levitan, senior vice president of Pacific Lighting Corp. He comments further that adequate action would not only eliminate the risk of a gas shortage, it would also lessen damage from another oil supply disruption.

Speaking at a utility financing conference in New York City, Levitan contended that the present U.S. gas surplus, combined with economic and political uncertainties, will result in a substantial drop in gas industry capital requirements during the next 5 years from what was expected only a year ago. The condition is produced by a combination between the NGPA and the long term producer-supplier contracts.

Levitan believes the gas surplus will disappear with the economic recovery, resumption of real oil price increases, and the drop in gas drilling. By the early 1990s, probably U.S. production, plus imports from Canada and Mexico will not meet U.S. demand. That would justify more expensive gas from Alaska, coal gasification and imported LNG. "However, the odds are high that these projects won't be built in time to avert serious domestic energy shortages."

As solutions, Levitan suggests a common sense regulatory approach and a sound, sustainable national energy policy. This includes reasonable returns on investment, rolling construction costs into the utility rate base, stability of tariffs, and recovery of prudent abandonment costs. Energy is necessary for national growth, while the state of the economy creates a disincentive for energy investments. "...the U.S. policy...should be aimed at securing additional supplies and not on allocating shortfalls."

#### Gas Research Institute

While made in June, 1981, a statement by Henry J. Linden, President, GRI, in "Current National Issues in Natural Gas Policy," is still noteworthy: "In the United States alone, this means we have at least 800 trillion cubic feet of conventional natural gas, plus 200 trillion cubic feet of tight sands, Devonian shale, and coal seam gas that can be produced at prices not too different from today's levels for new gas. This corresponds to a 40-50 year supply at annual production rates of 20-25 trillion cubic feet. When one adds the growing export potential of Canadian natural gas, the present large over-supply of exportable gas in much of the less-developed world, and the nearly unlimited potential of coal gas, the problem seems to be demand, not supply."

U.S. Average Wellhead Price of Natural  
Gas, Midprice Scenario, 1980 to 1990  
(1982 Dollars per Million Btu)

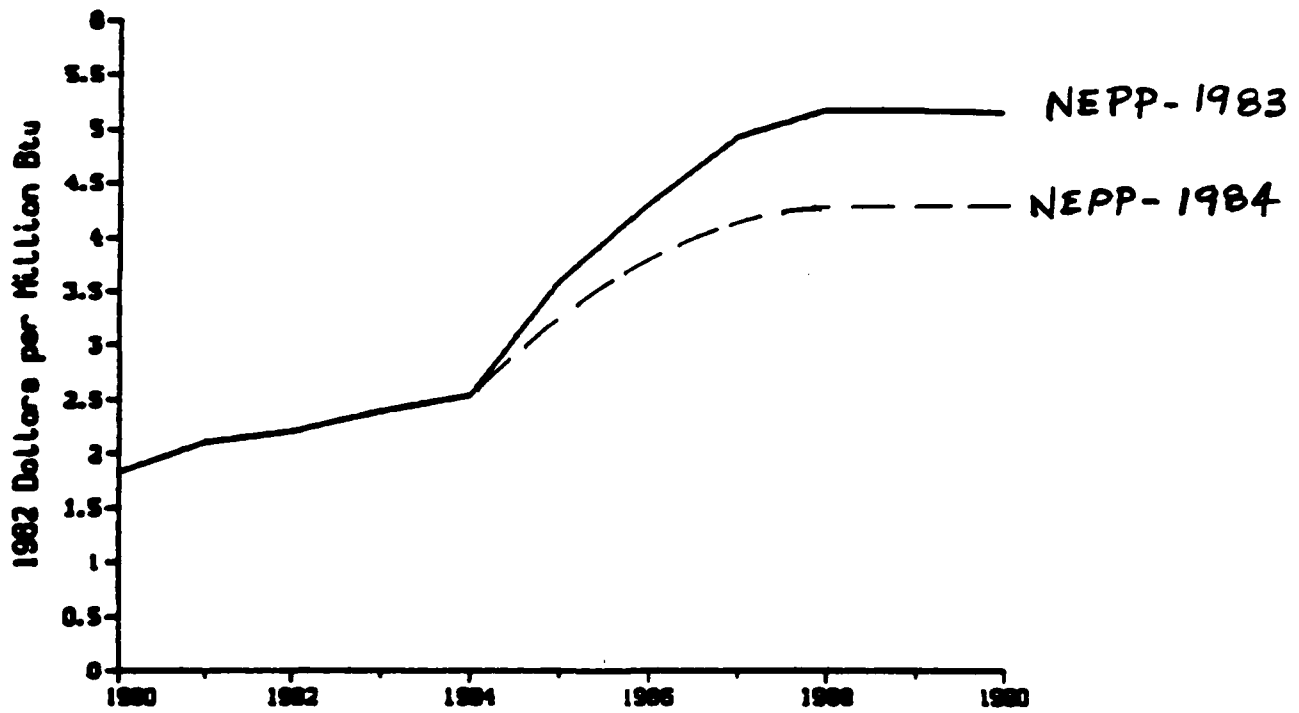


Figure 6-1

# World Oil Price Projections, 1970 - 1990

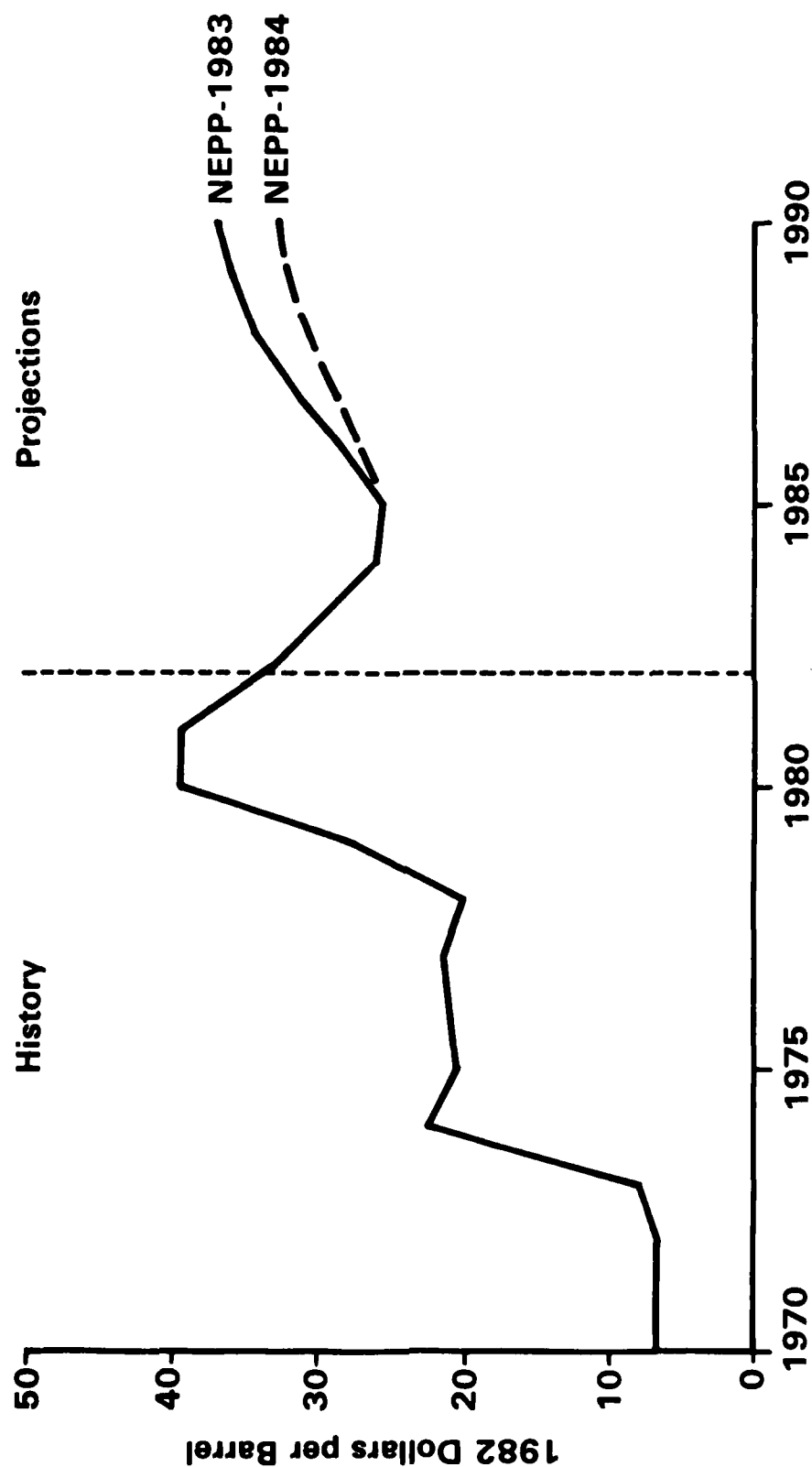


Figure 6-2

Chapter 7Alternative Fuels and Energy SourcesAutomotive Fuels

In 1982, U.S. transportation consumed almost exactly one-third of the energy used in this country, or about 63% of its petroleum, while aviation accounted for about 8% of the petroleum demand. As pointed out in Impact, aviation is not a significant factor in U.S. petroleum supply and demand. As a premium product, aviation fuel is a fairly important item for those refiners which produce it. But it does not drive the petroleum market in any sense. Aviation fuel price and availability are determined more by events and developments outside aviation than within the aviation community.

By contrast, automotive vehicles are currently using about 3/4 of U.S. transportation fuel. Aviation fuel users should therefore look to the automotive sector for the strongest indications of their destiny. As was shown in Chapter 4, EIA has forecasted that automotive fuel demand will continue to decline, driven to a substantial extent by continuing automobile fuel economy. While every individual in DOE may see it somewhat differently, it may be significant that the Office of Vehicle & Engine R&D now believes that the recent trend toward steady improvement in miles/gal has softened significantly in the second half of 1983. If so, U.S. gasoline demand and petroleum consumption may not continue to drop through and past 1984 as predicted by EIA, and petroleum prices may not fall quite as far as EIA expected.

While this is not yet a critical point and the trend is probably too new to carry major significance, it is noteworthy. Just as EIA's expected revision to lower natural gas prices in 1985 will lower the forecast world oil price, this new view on heavier autogas consumption may push the price of crude oil back upward. As has been observed before, while energy forecasts may be made for five, ten or more years into the future, they seldom remain valid for more than a few months.

But assuming that the EIA world price forecast is valid "as long as its ink is wet", gasoline prices should continue to drop through 1985. Then, if natural gas is deregulated and its price remains fairly constant, the price of motor gasoline and of aviation fuels could stay about constant until approximately year 2000. At any rate, before more meaningful information is logged to change that picture, we should expect no significant long-term change in automotive or aviation fuel prices or availability through this century. That is, also as long as there is no substantial disruption in world crude oil deliveries, a subject which is discussed in Chapter 9.

Now there appear to be only two circumstances under which

alternative automotive fuels may assume significance within the next thirty to fifty years: (1) in a petroleum supply emergency, and (2) if the total costs of using an alternative fuel is significantly less than using more convenient gasoline, say by 15-20%. The first condition, an emergency, cannot be analyzed rigorously for many reasons, including the question as to how alternative fuel prices may also be affected by emergencies. For example, the price of other fuels has followed the price of oil upward, while the cost of making synthetic fuels has also risen markedly through effects of energy costs on inflation and construction costs.

But lower costs for alternative transportation fuels will always present valid opportunities for fuel-switching, and the prospects for alternative automotive fuels are therefore dependent on their prices.

### Diesel

As reported in Chapter 4, David L. Greene of DOE has shown that use of diesel fuel in the United States should rise only at about the same rate as our GNP. This conclusion is drastically different from the picture presented in Impact and elsewhere, and this author now agrees with Greene. Having noted the rapid rise in demand for diesel fuel through 1982, almost all analysts concluded that the upward diesel trend was as valid as the downward gasoline conservation trend. Therefore, as demand for diesel was expected to grow steadily, some thought at even an accelerating rate, demand for gasoline should continue to drop.

Greene's analysis shows, however, that the rapidly growing demands for highway diesel fuel have come from rapid dieselization in U.S. heavy trucks. While U.S. sales of diesel automobiles also rose dramatically from 1977 through 1981, their numbers and fuel consumption were still much too small to affect the total diesel market. Greene then shows that dieselization of U.S. heavy trucks is now virtually complete, while further diesel switching by medium trucks and all U.S. buses could not significantly increase diesel demand further. This leaves the future automobile and light truck market as the sole possibility for expanding diesel demand dramatically.

Greene shows that diesel fuel prices now rival gasoline prices and that diesel automobile sales fell as rapidly in 1982 as they had risen in 1977-81, see Fig.4-8. In addition to this failing popularity for diesel cars, there has always been doubt that they would be able to meet future federal exhaust emission requirements. Reports more recent than Greene's paper confirm that auto diesel sales have fallen to 2.2% of new auto sales in the second quarter of 1983, down from about 6% during the past few years. Another ominous sign is that, while diesel car prices had been legitimately higher than for gasoline models, Volkswagen has now priced its diesel models below the price for comparable gasoline models.

In less than two years, the trend now seems reliably confirmed: diesel cars are not likely to penetrate a larger part of the auto market, demand for diesel fuel will be driven largely by heavy truck activity, and diesel fuel consumption will grow only at about the same rate as the GNP, which indexes the growth of heavy truck traffic.

A major conclusion of the Impact report is therefore revised: Expected growth of highway diesel fuel consumption no longer appears to pose a future threat to the price or availability of Jet A fuel.

#### Alternative Auto Fuels

The automotive picture apparently has resolved itself fairly clearly. Gasoline is expected to be available at reasonable prices through this century. The only significant opportunity for alternative fuels is for those which can promise some substantial cost advantage over gasoline. From the standpoint of easy fuel availability, service, parts, trade-in, etc., the present gasoline system presents a formidable standard which any alternative must clear by a tangible margin. Are there any valid candidates?

The chicken-and-egg problem confronts introduction of any new fuel, whether in stationary powerplants, transportation, aviation or automobiles. Perhaps in automobiles the element of convenience may weigh more heavily than in other modes, where economics may score higher in decision-making. This is one of the problems with diesels, where a small margin of inconvenience may convince car buyers that slightly better economics aren't worth the extra trouble. Fleet operators are able to minimize these inconveniences, while profiting from fairly small advantages in economy. Consequently, fleet operators may gravitate toward diesel or alternative fuels, wherever a clear economic benefit is indicated. But the public may not follow fleet operators.

In the recent past, fleet operation had been viewed as the avenue for introducing any promising alternative fuel. But today the view is more pragmatic. While some automotive fleets are sizeable and could affect fuel selection within a local community, realism has sunk in that only a very small fraction of U.S. automotive vehicles are operated in fleets. It is concluded that a new fuel might capture all the fleet vehicles in the United States without turning the private vehicle market away from gasoline.

Perhaps this realization arose from the tremendous effect of heavy diesel trucks on diesel fuel demand, and the recognition later that diesel demand is still only about 15% of highway motor fuel. So conversion of all heavy fleet trucks to a new fuel, plus taxicabs, plus delivery and service fleets, etc., etc., still would not assure capture of the automotive market by the

new fuel.

Now it is fully recognized that gasoline is not going to fade away. The question is whether some other fuel has a chance of deposing gasoline.

#### Methanol, Methyl Alcohol

Methanol probably stands the best chance for eventually replacing gasoline on the highway. First and foremost, methanol is generally cheaper than gasoline per Btu, although its price varies more in different localities and circumstances than does that of gasoline. Methanol is a common substance today, but its consumption is very low, not only in comparison with gasoline, but even in the chemical industry. Oil is the overwhelming chemical feedstock.

Perhaps the greatest potential for methanol lies in the tremendous surplus, and current waste, of natural gas in the Middle East and other parts of the world. As far as the U.S. is concerned, its large source of natural gas in Alaska constitutes a formidable problem, almost a liability. How can this considerable asset be brought to market? The Alaska gas pipeline plan was dropped not only because of its \$45 billion estimated construction cost, but also when it became obvious that it would deliver gas to the U.S. border at prohibitive prices, transported through Canadian territories which are themselves surplus with natural gas.

In, "Methanol is the Best Way to Bring Alaska Gas to Market," Oil and Gas Journal, November 1, 1982, Professor Donald F. Othmer of the Polytechnic Institute of New York discusses some of the issues.

Othmer points out that the 22% carbon dioxide and light hydrocarbons, which must be removed from gas out of the well to make it marketable as natural gas, are equally valuable raw materials for making methanol from methane. In fact, a natural gas separation plant is estimated to cost \$6 billion, while about a third more methanol can be produced from the raw gas than from the methane alone. More net energy would be delivered as methanol than as clean natural gas.

A separate methanol pipeline could be built from the North Slope to Valdez, where the methanol could thence be shipped by sea. This pipeline would not require insulation. Or the methanol can be transported in batches through the same pipeline as oil. From Valdez, it can be moved in standard tankers. Interestingly, while Alaskan crude cannot be exported outside the U.S. by law, Alaskan methanol could be shipped to Japan and other Pacific markets.

Othmer estimates that the North Slope could produce about 8 billion gallons of methanol per year (small in comparison with



the more than 100 trillion U.S. annual gallons of gasoline) from three plants costing around \$3.5 billion each, for a total of around \$10.5 billion. This cost does not compare unfavorably with \$6 billion for the gas separation plant, considering that compressors will also be required to move methane gas, plus the \$45 billion pipeline required for its exclusive transport to the Lower 48. A gas pipeline only to Valdez provides no solution unless a gas liquefaction plant, loading terminal and dedicated cryogenic ships are added, to move the resulting LNG out of Alaska.

Othmer suggests this methanol produced from Alaskan NG could be used in highway vehicles, for generating electricity (by gas turbines), or later converted to synthetic natural gas, SNG. He concludes SNG by the methanol route would cost about half as much in the Lower 48 as would natural gas delivered by the proposed gas pipeline. He does not mention the possibility of using methanol as a chemical feedstock, which may become its ultimate largest application, unless it replaces gasoline in a large number of automotive vehicles.

Alcohols contain oxygen. Considering that hydrogen is the most efficient component of hydrocarbon fuels, a fuel which also contains oxygen already has been "partially burned." The oxygen in combination with some of its hydrogen is effectively water. Methanol is unlikely to find much application in aviation because a pound of methanol contains about half as many Btus as a pound of gasoline. Methanol is therefore a heavy fuel in an airplane; its weight detracts from the airplane's range-payload performance. Nevertheless, some experimenters with piston-engined aircraft are methanol enthusiasts.

Due to octane advantages, cleaner burning, cooler flame and other attributes (some conjecture that the oxygen in methanol may contribute to better engine altitude performance), aviation methanol proponents contend they have been able to match the aircraft miles/gallon performance of gasoline. This claim will remain in doubt until measured with reliable instrumentation. If confirmed, methanol could be a convenient substitute for aviation gasoline, although that represents only about 5% of aviation fuel used. Noone has contended that methanol could compete with gasoline performance in aviation gas turbines. Combustion in gas turbines is already over 99% efficient, while octane rating means nothing in an open cycle.

Even in automobiles, methanol is considerably heavier than gasoline, posing some operating problems. Methanol engines are also difficult to start because of its low vapor pressure. Generally, rather than using neat methanol in automobiles, 10% gasoline would be added to improve starting characteristics. Methanol attacks some materials in conventional auto fuel systems, but Ford is at least one manufacturer which has produced and will deliver methanol cars for fleet operators. Presumably the current slump in gasoline sales has deferred Ford's plans for

offering methanol-fueled cars to individual customers, on essentially the same basis as diesel cars have been marketed.

But methanol does rate an effective octane number over 120, and therefore offers the opportunity of using diesel-type compression ratios in spark-ignition engines, for higher fuel mileage than with conventional gasoline engines. Its exhaust emissions are probably more benign than diesel.

All in all, methanol is not a bad auto fuel; it is probably fair to say it is a pretty good one. Aside from the question of net cost, the chicken-and-egg problem of fuel distribution/market demand is probably its greatest obstacle. It may present a sociological problem as being toxic if drunk as a beverage, being what has been popularly called "wood alcohol".

But methanol also has the advantage that it can be produced fairly easily from any hydrocarbon, plus water. It can be produced from coal, lignite, peat, and all kinds of biomass, including wood, trash, garbage, sewage, animal and industrial wastes. In some cases, production of methanol may be a desirable way of eliminating otherwise undesirable wastes; part of its cost may be offset by reduced cost of waste disposal. So, depending on how the cost accounting is done, methanol could find opportunities for entering the market.

As seen by the example of Alaskan natural gas, capital costs will be immense for any sizeable production of methanol. But the same must be said for any other liquid transportation fuel, or any synthetic fuel. Their capital costs will be large and, in transportation, they must compete directly with the established gasoline system.

#### Liquid Natural Gas, LNG

From Professor Othmer's analysis given above, one would conclude that methanol will be generally cheaper than LNG. As in so many fuel and energy matters, the outcome depends to a great extent on one's assumptions, as well as on conditions that develop at some time in the future. Further, regional or local conditions may work to the advantage of one fuel over another. It has been noted by some, for example, that magnetic liquefaction may reduce liquefaction costs by as much as 40%. But magnetic liquefaction is still in the laboratory stage. And who will exploit its potential until there is an indicated market for LNG or LH<sub>2</sub>? There are many levels of chicken-and-egg relationships.

Methanol holds some clear advantages over LNG. It is a liquid, conveniently handled at room temperature, by essentially conventional methods. While it does not vaporize easily and therefore enjoys some safety advantage over gasoline, it burns with a nearly invisible flame, which increases its danger. It has been the predominant fuel for many years at the Indianapolis 500, so some practical experience with methanol is available.

While methanol can be thought of as methane gas liquefied by a water molecule, LNG can be thought of as methanol with the water removed. From an aviation viewpoint, it is crucial to leave out the weight of all that water. Even in an automobile, for equal operating range, a filled LNG tank is about the same size and has a lower weight than a filled gasoline tank, while the comparable methanol tank is twice as large and twice as heavy as either.

By today's economic groundrules, Othmer's analysis shows it is generally cheaper to liquefy natural gas by converting it to methanol than to clean and liquefy the natural gas by reducing its temperature to  $-259^{\circ}\text{F}$ . Once at  $-259^{\circ}\text{F}$ , however, and with a cryogenically insulated fuel tank, LNG is a superb fuel.

LNG vaporizes directly to gaseous methane, the simplest and cleanest of all hydrocarbons,  $\text{CH}_4$ , having four atoms of hydrogen bound to one atom of carbon. An automobile, for example, requires no carburetor for methane, only a simple pressure regulator which has been used for years in metering gas and in propane-powered industrial and farm equipment. The exhaust from an LNG engine emits carbon dioxide, rather than toxic carbon monoxide. LNG engines, therefore, can be operated in factories, garages and other confined spaces without danger to the human occupants.

Since it vaporizes above  $-259^{\circ}\text{F}$ , a methane-powered engine will start easily in any climate. Since its octane equivalent rating is above 120 (on some bases, about 130), a piston engine designed to run on methane may use compression ratios around 16, competing with diesel engine thermal efficiencies. But a methane engine does not share the starting, exhaust and dirt problems of diesels. In fact, other than hydrogen, it is the cleanest fuel. It produces no sludge, gum, varnish, carbon deposits and, with its low-intensity internal flame, it imposes lower temperatures and thermal stresses, does not tend to burn valves, and has other attributes within the engine. Engine maintenance should be drastically reduced, tune-ups virtually eliminated, oil changes extended dramatically, and engine life greatly extended.

Aside from straight cost of the liquefaction process, the chicken-and-egg introduction problem is formidable with LNG. Storage is not particularly difficult, thanks to developments through the NASA space program. Beech Aircraft and others, who have developed cryogenic tanks and equipment for space vehicles, are offering LNG conversions for automobiles, in which the customer can convert completely to LNG, or may retain the existing gasoline fuel system and, at his option and using a selector switch on the dashboard, operate his car on either LNG or gasoline. Fuel switching may be accomplished even while the car is under way. This type of installation markets for less than \$2000.

In a Beech installation, the cryogenic tank vents at about 20 psia, or 5 psig, simply to delay boiloff from the time the tank

is fueled. According to Beech, their standard 18-gallon tank does not vent any vapor for about ten days in average storage. At that point, venting is about one cubic foot of gas per hour. This amount might be ignored, vented to the outside from a garage, or even returned into the municipal natural gas system. However if the car is operated at any time during the ten-day period, the tank is returned to zero time.

Beech has operated an LNG-powered car in the Washington area for several years, parking it in the basement garage of its office building. During this time the tank has not yet vented, because of fairly frequent use. Although the car can operate on either gasoline or LNG, it has not been driven with gasoline. Baltimore Gas & Electric maintains a terminal for LNG imports from Algeria, so that fuel is available in Baltimore, and at about 150 other terminals in the U.S., for about 55 cents/gal. Long-term LNG storage is practical. Municipal gas distributors receive LNG shipments year-round, but use the gas to supplement gas peak load demands during the winter months.

Beech is enthusiastically pursuing the automotive LNG market, with the hope of building a base of experience for introducing LNG into general aviation.

It is noteworthy that methane, like methanol, can also be produced from all types of hydrocarbons, including coal, peat, biomass, organic wastes, and the like. Beech is active in these fields, including methane from landfills, from city sewage, from chicken manure, etc. Beech offers its experience as program architects and managers, assembling systems with available industrial equipment for collecting, cleaning, liquefying and storing the methane, then offering Beech-developed equipment for final fueling of the vehicles, and the LNG fuel system within the vehicles themselves. Other manufacturers offer similar services or systems.

This author believes methanol and LNG are at close to a dead heat in their ability to replace gasoline for U.S. highway vehicles. Methanol has an edge in being a more conventional fuel and in the likelihood of its worldwide production. LNG has the decided advantage of being a superior fuel and, as far as aviation is concerned, an attractive replacement for aviation gasoline, as well as a practical replacement for jet fuel.

Much depends on how the future develops. If world gas producers begin manufacturing methanol and offering it as worldwide cheap energy, that should set the course. If natural gas deregulation is successful in the U.S., and gas prices remain reasonable or drop lower (as the author believes they should), and/or if magnetic liquefaction becomes economical on a large industrial scale, LNG would be an outstanding fuel. But, if U.S. natural gas does succeed in becoming unregulated and cheap, probably the demand for petroleum will drop so drastically that petroleum prices will be kept low for at least another generation.

Liquid Petroleum Gas, LPG and Compressed Natural Gas, LNG

Although chemically different, and different from a safety viewpoint, LPG and CNG are discussed here together briefly. While they offer some attractive advantages in special applications, neither offers much possibility for fueling highway vehicles--the fuel systems are too heavy for reasonable vehicle ranges. Consequently, in the opinion of this author, neither has a serious potential for fueling aircraft. Nevertheless, there have already been some flight tests using LPG as an aircraft fuel. It could be observed that airplanes can be flown with corn oil or French perfume when cost and weight are not important.

If an aircraft operator feels he has access to a supply of LPG at a cost attractive enough for him to seek an operating certificate, in the view of this author and of the FAA, he should receive every cooperation in doing so. But cooperation does not mean that the idea is considered practical or economical.

LPG is in shorter supply than gasoline and it sells for comparable prices. LPG is particularly useful for fork-lift trucks and other internal-combustion equipment inside factories and other enclosed areas because its exhaust emissions are low in toxic carbon monoxide--this desirability tends to hold its price firm. Therefore, it is not apparent why LPG should be attractive to anyone in aviation. Conceivably, someone may own an airplane in an oil- or gas- producing area where LPG is a plentiful byproduct, and far enough from industrial areas so that the LPG would be expensive to get to market. LPG is not attractive for highway operation for essentially the same reason--it has no price advantage and it is in short supply.

The situation in New Zealand is considerably different from in the U.S. because it produces considerable natural gas, with LPG as a byproduct, but does not have extensive industrial activity. So the New Zealand government encourages the use of LPG in automobiles, although LPG can accomodate only a small amount of the country's highway demand.

LPG is gas liquefied under pressure at room temperatures. By contrast, LNG and  $LH_2$  are cryogenic fluids; they are liquefied by very low temperatures at atmospheric pressure. Since LPG supplies and bottles are fairly portable, LPG is a popular fuel in recreational vehicles and in residences inconvenient to natural gas supplies. LPG is the popular "bottled gas".

Depending on content of the LPG, in percent of propane, butane and other gases, it may be pressurized from about 100-300 psi. Because of this pressurization and the fact that the gas vaporizes immediately when pressure is released, LPG is not an attractive fuel for airplanes. First, the pressurized tank and fuel lines are more prone to leak. But more significant, in case of an accident which ruptures the fuel system, fires can be serious to catastrophic.

Unfortunately, this LPG safety hazard has been taken as an indication that all liquefied gases are dangerous. Since LNG is liquefied by low temperature, its system is pressurized only to some low, nominal level. LNG does not immediately gasify in case of a system rupture. A cigarette will be extinguished in a pool of LNG; tracer bullets can be fired through its tanks without ignition. But the local ordinances which often prohibit transport of LPG across certain bridges or through tunnels, usually are written so that they apply equally to LNG.

If LPG were used by general aviation, the added demand would be low enough so as not to interfere too much with the industrial, remote residence and recreational markets. On the other hand, considering that when the economy is healthy and more private owners wish to fly their airplanes, that is the time they will face competition for LPG from the other recreational users. And, a switch now of some aviation demand from gasoline to LPG would not appear attractive at a time when demand for gasoline is still falling. At any time, some new industrial use for LPG could develop a new demand and justify LPG's special attributes as a high-priced fuel. Aviation might find itself priced out of the market.

Since there is currently no general price advantage, since the market is small and aviation could be the victim of future market developments, and since LPG presents appreciable safety hazards, LPG offers little appeal in aviation.

Methane is a clean, energetic fuel with many advantages. When LNG is liquefied by low temperature, a tank will hold about 600 times as much methane at atmospheric pressure as it would at room temperature. But when methane is at room temperature, as more fuel is added to a tank to increase vehicle range, the tank pressure must rise. For use in ground vehicles, methane is usually compressed to 2500-3000 psi. The tanks are very heavy, comparable to the high-pressure industrial tanks used for bottled hydrogen, nitrogen and acetylene. These usually weigh about a hundred pounds apiece and, with CNG, hold about the equivalent of a gallon of gasoline.

A typical car fueled by CNG is limited by weight to about two such high-pressure bottles and the car's range is therefore limited to about a hundred miles. So the missions for CNG vehicles are similar to those for electric vehicles, where battery weight is often about half the weight of the vehicle.

CNG vehicles have been fairly popular in Italy since WWII and Italy has developed special tanks which are lighter than those used industrially in the U.S. In its study of how to use its natural gas supply, New Zealand is said to have studied derivable alternative fuels as much or more than any group. They will convert much of their natural gas to gasoline by the Mobil M process, with deliveries scheduled to start in 1986. In the meantime, their government has provided both LNG and CNG filling

stations for citizens and industry who convert vehicles for either of these fuels. It is understood that LNG is fairly popular, but that CNG has not made much penetration in New Zealand.

While an aircraft engine could be easily powered by CNG, the weight of the fuel tanks would be completely prohibitive.

#### Ethanol, Ethyl Alcohol, "Grain Alcohol"

Like methanol, ethanol can be manufactured from petroleum, by way of ethylene. Industrial ethanol is made by this process for the fairly small demand of 100 million barrels a year. But, by this method, the price of ethanol is higher than for methanol or gasoline. Ethanol is not basically attractive for fuel uses; its attraction arises from the fact that it can be made from surplus agricultural products. With suitable tax advantages and other incentives, it can be made competitive for fuel additive purposes. Support for fuel ethanol depends on a given nation's economy and interests; it may vary from time to time.

As is well known, Brazil has produced cars to run on ethanol made from sugar and cassava products. More recently, with the rising world price of sugar, Brazil may be in a no-win situation. Its "alcogas" is said to be now trending more toward "gasohol".

Like methanol, up to around 10% ethanol can be mixed with gasoline as an octane extender, raising the octane number by 2 or 3 points and essentially converting standard unleaded gasoline to medium-grade or premium unleaded. The ethanol is considerably more expensive than the gasoline but, as an anti-knock agent, is about competitive with higher-octane auto unleaded gasoline. Its cost is also assisted by tax advantages, both state and federal. Previously marketed and advertised as gasohol, it is currently usually identified only in the fine print.

In the U.S. today, some 300-400 million gallons of ethanol is being used in automotive fuels. This may seem a rather sizeable amount when compared to the industrial ethanol consumption. From the automotive standpoint, however, this use is trivial compared to the approximately 100 trillion gallons of highway fuel used in the U.S. annually. But it is enough to interest U.S. distillers and, for some time, U.S. farmers seeking a wider market for their grains.

Ethanol produced for human consumption is made from fruit or grain into wine, beer or whiskey. These feedstocks are too valuable for fuel purposes. Also, while ethanol can be made from a variety of sugars, or starches which can be converted to sugars, the process is through fermentation into alcohol by live bacteria. Conditions must be clean enough to be favorable to the bacteria and the process is inherently slow.

Following fermentation, the alcohol must be separated from the

remaining liquor, which has a very high water content. Up to 95% water can be removed by distillation of increasing sophistication but the last 5% must be absorbed by chemical means. And it is very important that all the water is removed, yielding 200-proof ethanol. When alcohol is mixed with gasoline, a very small amount of water can cause both the water and the alcohol to separate from the gasoline at low temperatures. This quality also suggests problems in using any gasoline-alcohol mixture.

As suggested above, whole grain is normally too valuable as an alcohol stock. But the most valuable component of the kernel is its germ, which contains the oil. For manufacturing corn oil, a wet grind process is used which separates the grain's germ from its starches and fiber. These starches can be made into several types of sweeteners. But the market for the available corn oil is greater than that for the resulting sweeteners, starches and fiber. Consequently, at lower cost than using whole grain, excess starch can be made into sugars and then fermented into alcohol. This process is still not directly financially feasible for fuel purposes, but taxes and other considerations make up the difference.

Another financial attraction has been the guaranteed loans offered first through DOE and then from the U.S. Synthetic Fuels Corporation for constructing of four pilot project ethanol production plants. These loans have been fully subscribed and no further guarantees are likely to be extended. We have nearly completed the second round of ethanol benefits and there is not likely to be a third. It appears that U.S. farmers now recognize that fuel ethanol offers no panacea and, while moderate interest will no doubt continue, the political pressure has greatly subsided. In the past, Congress has insisted that gasohol should be considered in military tactical fuel planning; it is unlikely that an edict to promote ethanol will be continued in the future.

Fortunately, perhaps, fuel ethanol is both too expensive and too heavy for serious consideration in aviation. It also does not offer much potential as a highway fuel or appear to otherwise affect petroleum markets. Ethanol is therefore unlikely to affect the aviation fuel market in any tangible way. Ethanol may offer its greatest interest as an illustration of how an expensive, generally unsuitable product can be introduced into a highly competitive market through tax benefits and other special concessions.

### Hydrogen

Hydrogen is not a source of energy, but simply a form of energy. It does not occur in nature, but must be separated from other substances, such as stripped from hydrocarbons in petroleum or other fuels, or split from oxygen in water. If produced from liquid hydrocarbons, the hydrogen is almost certain to cost more than other fuel which could also be produced. In the U.S. economy, electricity is generally too expensive to use for



splitting water into its components, although there is a good market for oxygen.

There is considerable foreign interest in hydrogen, particularly in countries which have an electrical situation different than our own. Eastern Canada, for example, already produces more hydroelectricity than it can consume, while it is also selling about as much surplus to the N.E. United States as the market will bear. But Canada has more hydroelectrical sources which could be tapped; their interest in hydrogen is fairly active.

Even some Canadian powerplants which burn fossil fuels to produce electricity have active programs to develop hydrogen for peak shaving power during high periods of electrical demand. The decision is purely one of economics. During low demand periods, the plant can produce excess electricity, which it may use to manufacture hydrogen from water, having a favorable market for the oxygen it also produces. During peak demand periods for electricity, the plant can burn the hydrogen in gas turbines (presumably aviation-type gas turbines). Under these circumstances, it may be concluded that the plant finds its hydrogen cheaper than buying jet fuel for the turbines.

In another case, a proposal, rather than an actual industrial endeavor, a Southern California utility consortium sought to manufacture and liquefy hydrogen from Montana coal, which was already being shipped to the California desert area for manufacturing electricity. By selling byproduct electricity to powerplants at the site and surplus electricity to the utility, as well as making some heavy water for Canadian fission breeder reactors, the consortium sought to produce 100 tons of  $LH_2$  per day and deliver it to Los Angeles Airport at a price per Btu lower than that of jet fuel. That proposal at least suggests that there may be conditions under which hydrogen can be produced in competition with existing fuels.

It may be worth repeating here the conclusion in Impact that, other than magnetic liquefaction, there are no known prospects for significantly reducing the cost of liquid hydrogen. Cheap electricity appears to offer the best prospect. Or, as seen above, unique accounting and marketing of byproducts, may offer some feasible avenues.

In anticipating the future for energy, it is probably more important to have flexibility than conviction. The present petroleum picture and the future indicate that petroleum still has a long run in the market. Alternative fuels may have a long wait before making any real entry. The tremendous resources of shale, coal, peat and probably gas, may continue to crowd hydrogen off the entry list. But things may change at any time. Other nations account for their costs differently than we do. Coal is being liquefied in South Africa; gas will be converted to gasoline in New Zealand. When the French are well supplied with fission breeder reactors, electricity may become cheap in their

economy and hydrogen may become an attractive portable fuel to them.

The reason for including hydrogen here is not because it is expected to influence aviation in the near future. But hydrogen should be viewed constantly as a candidate in the fuel contest. Liquid hydrogen is attractive enough in aviation so that, if it should become economical, it could affect aviation early in its career. But there is no reason to galvanize aviation interest toward hydrogen. Although it will take ten years to develop the new airframe-engine combination to realize the full value of LH<sub>2</sub>, there should be ample warning to the aviation community before hydrogen can become available in sufficient quantities at a competitive price.

### Synthetic Fuels

As a base point, it is convenient to refer back to NEPP-1983 and consider the DOE's forecast for the part that synthetic fuels should play in the U.S. petroleum picture. DOE's projection is not fine-scale and it does not show the contributions of synthetic R&D projects, only synthetic production in multiples of 100,000 BPD. But that is probably a practical view. It does not show any synthetic inputs to the oil market until year 2000, when the contribution is 100,000 BPD, less than 1% of U.S. domestic oil production at that time. But activity begins to build fairly rapidly, with production reaching 500,000 BPD in 2005, nearly 4% of domestic oil output and, in 2010, rising to 1.5 million BPD, almost 12% of domestic oil production. So DOE considers shale a definite contender, but considerably delayed into the future.

DOE's timing for introducing synthetic fuels is necessarily sensitive to the rate at which they see the demand for OPEC production rising above the OPEC price threshold, about 80% of OPEC production capacity at any given time. The DOE forecast for synthetic production penetration also depends on assumptions as to how the costs of shale-oil production will react to the general inflation pattern (as oil prices rise, the cost of synthetic fuel plants rises). It is notable that DOE does not include any other synthetic fuels in the oil picture, only shale oil.

DOE does anticipate that coal liquids will begin to become available at the same time, year 2000, and in the same quantity, 100,000 BPD in that year. That fuel is assumed to be used in generating electricity. But the coal synthetic industry grows at a much slower rate than that for shale oil. It increases to only 200,000 BPD in 2005, and to 700,000 BPD in 2010, less than half the growth rate for shale oil.

In any case, at least as seen by DOE in NEPP-1983, no synthetic fuels will affect the U.S. energy picture until 2000, while their rate of introduction will remain quite low for some time thereafter. But that is projecting far enough ahead so that no

synthetic fuel project manager should be particularly perturbed by these conclusions.

### Alternative Stationary Fuels and Energy

#### Coal

Most of the material here is taken from "New Technologies for Burning Coal," DOE/FE-0030, December 1982 and the Navy Energy Fact Book of 1979, published by OP-413.

As is generally recognized, anyway it's measured, the United States holds a colossal amount of coal, more than any other country in the world and more than a quarter of the world's total supply. According to the World Energy Conference of 1977, the U.S. has almost 28%, with the USSR second at just over 17% and China third with 15.5%.

In 1976 our proved reserves were 438 billion tons and, since our greatest rate of production has never exceeded a billion tons a year, those reserves will last a long time. In addition to the proved reserves, our total estimated U.S. resource, mapped and explored, is 1,734 billion tons. Adding the unmapped and unexplored estimate, we show a grand total of nearly 4 trillion tons. If mined at a billion tons a year, that rounds out to a 4,000-year supply.

In 1982, the U.S. produced over 833 million tons of coal, up from about 824 million in 1981 and 563 million back in 1973. Of the 833 million tons produced, we used 707 million domestically. Almost all of our consumption is in electrical generation or as coke in industry; in 1983, almost 600 million tons was burned in electric utilities. The 833 million tons produced is about equivalent to 3.6 billion barrels of oil, or about ten million barrels of oil a day. That recalls an earlier observation that our domestic coal production is about equivalent to our domestic oil production (as well as our natural gas production).

So our limitation on using coal lies not with the supply. The problems with coal are in handling and burning it cleanly. Although improved technology will help coal to be used more, in 1973 the price difference between coal and oil was only about \$2 per barrel oil equivalent. Today the difference is more than \$20/bbl. With that price difference, considerable expense can be borne to make coal environmentally acceptable. The largest problem with coal is in its sulfur content.

The sulfur content in coal varies considerably from region to region and even in the same seam, varying from less than 1% to as much as 6-7%; 2-3% is the most common. But a single seam can vary as much as the maximum. In general, eastern coal is high in sulfur, but it accounts for nearly 75% of the coal presently mined.

Sulfur occurs in coal both as heavy iron pyrites, which can be removed by grinding and washing, separating about 20-50% of the sulfur, or as organic sulfur, bound with the carbon atoms. When coal is burned, most of the sulfur is released as  $\text{SO}_2$ , accounting for about 60% of the sulfur dioxide produced by man. In the U.S. these emissions are about 17 million tons of  $\text{SO}_2$  from coal, out of the 30 million tons total released annually in the U.S. Coal burning produces some nitrogen oxides ( $\text{NO}_x$ ), which is also produced by other combustion processes. The nitrogen in  $\text{NO}_x$  comes from the air and the combination takes place at temperatures of around 2,800° F. These compounds absorb some wavelengths of light and can react with hydrocarbon vapors in the air to create smog. Coal can be burned in stages to reduce temperatures and the  $\text{NO}_x$  emissions.

Carbon dioxide is also, of course, a major product from coal combustion. The concern over  $\text{CO}_2$  is with its potential "greenhouse effect" in warming the atmosphere; a recent EPA study report on  $\text{CO}_2$  repeated concerns and questions which have already been expressed earlier. The Energy Security Act of 1980 requires the National Academy report results of their comprehensive study to the Congress before June 30, 1983.

Sulfur dioxide emissions from coal were originally limited to a specific quantity that could be released for a given amount of heat--1.2 pounds of  $\text{SO}_2$  for each million BTU (about a thousand cu ft of gas, or a fifth of a barrel of oil). New standards of 1978 require that 70-90% of the sulfur be removed, depending on the coal's sulfur content. Ironically, this means that all plants burning coal must have emission control devices, regardless of how low the sulfur content of coal burned.

Sulfur is removed from stack gases by wet scrubbers, which wash the gas with a lime solution; a scrubber can contribute as much as twenty percent to a power plant's cost. The calcium sulfite residue is a wet sludge the consistency of toothpaste. Because it absorbs moisture from the atmosphere, it never dries. During the lifetime of a typical 500 Mw powerplant, the scrubber will require a disposal pond of more than 500 acres, 40 ft deep. So ash is by no means the only disposal problem from a coal-fired power plant.

Particulates are removed from the exhaust products by either electrostatic precipitators or bag houses, which are 40- to 50-foot long array of bags that work like a household vacuum cleaner. Baghouses are simple, but the power used in their fans make them less economical for larger utilities. But these systems permit coal to be burned cleanly at costs still less than burning oil.

The Federal emission control program is working to develop a sequence of advanced coal cleaning steps leading to attain the emission quality of fuel oil. This goal will require removing up to 90% of the coal's total sulfur and ash before the exhaust is

released. As implied above, coal can be cleaned at the mine, where about 20-50% of the sulfur can be removed now, not enough to meet environmental standards for new power plants. To achieve the 90% goal, sulfur and ash must be removed by grinding the coal from today's 1/100th of an inch to 1/1000th of an inch, the consistency of talcum powder. DOE hopes to improve this physical cleaning to extract more than 75% of the pyritic sulfur and ash.

The surface characteristics of coal tend to attract oil and repel water so, when fine ground, instead of separating by gravity, the coal can be coated with an oil-based substance that adheres only to the coal. The mixture is fed into a froth flotation cell where mechanically agitated air bubbles adhere to the coal particles and float them to the surface, leaving ash and other minerals in the tank. In a similar operation, after coal is coated with the oil-based liquid, the mixture is violently agitated to agglomerate the coal into larger particles that can be separated.

Pure coal is slightly diamagnetic, weakly repelled by a magnetic field. Pyritic sulfur is slightly paramagnetic, attracted by the field. An advanced coal cleaning process is being based on this principle.

Unlike physical coal preparation, chemical cleaning removes substantially all the pyritic sulfur plus varying amounts of organic sulfur. Several chemical processes are in their early experimental stages and costs will be higher than for conventional physical cleaning. Another experimental approach uses microwaves, which pass undisturbed through wet coal, but not through impurities. These two processes together have reduced ash and sulfur by nearly 90% in laboratory tests.

The wet coal must be dewatered in centrifuges, vibrating screens, filters, or thermal driers, none of which works well. So DOE is working with chemicals known as "flocculating agents" that cause small coal particles to mass together following cleaning. Fine coal assists in cleaning but poses problems for bulk shipping. Research is also under way to develop low-cost, low-moisture binders that will reconstitute the coal into sizes more economical for shipment.

Recent work in stack scrubbing has shown that by careful control of humidity and temperature inside a spray drier, more than 90% of sulfur from eastern coal can be captured using only about half as much lime as previously thought. Efficiency of conventional scrubbers has been improved by adding chemicals such as adipic acid. Dried scrubber sludge has been blended with fly ash, lime and cement and compressed into blocks. Today's research is being aimed at removing SO<sub>x</sub> and NO<sub>x</sub> in a single step, rather than by current expensive and less effective multiple steps. By contrast, a two-step electrostatic precipitation system promises to remove unburned particles at about half the capital costs of conventional systems.

One of the most promising methods for removing pollutants and completely eliminate the need for scrubbers, is fluidized-bed combustion, inside the boiler itself. A conventional boiler burns coal blown in at several levels, permitting the hot combustion gases to swirl up and out of the boiler. Fluidized combustion suspends a mixture of coal and limestone, the "bed", on upward-blowing jets of air. The mixture acts like a turbulent, boiling liquid--hence the name "fluidized bed". The limestone, chemically changed to lime in the combustor, absorbs the sulfur dioxide before it reaches the stack.

Since combustion temperatures in fluidized beds range from 1450 to 1700°F, significantly less than the 2700°F of a conventional boiler, output of nitrogen oxides is reduced by about half. Fluidized bed boilers are also more compact and should cost slightly less, while they operate well in smaller sizes and therefore should find wider application.

The "grandfather" of U.S. fluidized bed coal combustors is a 500-Kw unit built around 1965 in Alexandria, Virginia, with funds from the Federal coal research program. This unit confirmed the design principles and has led to improved methods for coal feeding and later industrial-scale fluidized-bed combustors. A newer 10-Mw unit at Georgetown University in Washington began burning high sulfur coal in 1979 which, in a test program to 1982, confirmed that the fluidized bed concept could meet the stringent air pollution standards.

Based on these and other units, industry is now working on commercial installations, while DOE is working on a new cycle of development. One idea would force pressure pulses through the bed to improve combustion, like the pulse-combustion gas furnace, which operates in principle like the German V-1 buzz bombs to increase compression ratio above atmospheric.

In another version, by pressurizing the system to 6-16 atmospheres, the boiler output contains enough energy to power a gas turbine-generator, plus produce steam for another turbine. This type of combined cycle offers efficiencies up to 40%, compared to the 32-34% for conventional coal-fired power plants with scrubbers. Recalling Fig.1-1, this type of development will assist in reducing the 26.2 Quads of end-use losses, which accounted for over 30% of the total energy consumed in the United States during 1982.

But these combined cycles erode and corrode turbine blades, unless particles can be separated out, blades can be protected by coatings, or other protections devised. Curtiss-Wright is working with DOE on a 13 Mw pressurized fluidized-bed power plant at Woodridge, New Jersey and has developed methods for both separating particulates and coating turbine blades. This unit should start tests in 1983, operating on funds from an industrial group. DOE is also working through the IEA with the UK and the FRG to test a pressurized system which began operation in

Yorkshire in 1980 and should continue through 1983. The UK is also studying the fluidized bed system's ability to adjust demands for electrical load following.

Finally, coal-liquid mixtures offer another avenue for improving coal handling and combustion, to make it more competitive with oil and gas. This principle dates back to trials by the Cunard Company and the U.S. Navy in the 1920s. Before the first oil crisis, many utilities switched from coal to oil, but are now unable to switch back to conventional coal because of insufficient space for coal-handling equipment. Coal-liquid mixtures may offer alternatives.

Coal-water slurries may contain up to 70% coal, and use no oil at all. Such a mixture was used by Jersey Central Power and Light in 1961, but no further work was done until the mid-1970s. Working with DOE, Atlantic Research Corp. in Alexandria, Va. has shown that stable mixtures of coal and water can be prepared, stored and handled like coal-oil mixtures. More important, conventional oil-handling equipment can accomodate coal-water slurries with modest modifications.

Today, DOE has begun a three-year research program with Combustion Engineering, Inc. and TRW to build a data base on the handling and combustion of coal-water mixes. Work is also underway on coal-methanol, coal-ethanol and other hybrid coal fuels.

Coal burning has already progressed significantly from the 1940s. Some of today's coal-burning plants are cleaner than ones which burn oil. Improved techniques, including better coal preparation, combustion and scrubbing all promise to provide a better market for coal in the future. Many utilities and industries may switch to coal-oil or coal-water slurries, depending on capital costs of systems now under development.

And, lurking in the background, there are possibilities for better and cheaper ways of converting coal into liquid fuels, including methanol, gasoline, diesel and jet fuel. Methods exist; if the cost improves, they can become very important. While coal may appear a mundane and farfetched subject to the aviation community, both by replacing oil and gas, and perhaps by contributing transportation fuels directly, it may eventually have major effects on aviation's ultimate destiny.

In its analyses for NEPP-1983, DOE/EIA concludes that U.S. coal consumption will increase more than for any other form of energy. From about 30% of the nation's domestic energy production today, it is expected to increase to over 40% in 2010.

### Synthetic Fuels

Synthetic fuels and oil from shale were discussed at some length in the Impact report and there is little additional to review at

this time. Already, before Impact was published, Exxon had bought out Tosco's (The Oil Shale Company) share in their joint Colony Project, which was to have been the largest development in the industry. Exxon has the program on hold and is apparently prepared to resume activity if energy and economic conditions look favorable.

Occidental has completed its operation with two full-scale retorts with favorable results but, pending market conditions and encouragement from other financial sources, is also in a dormant condition. There are some much smaller efforts which are continuing under previous or joint agreements, but none of these is expected to affect the energy market short of unexpected turns in the technology or the market. Like enhanced oil recovery, a significant effort seems just beyond reach.

Union Oil, however, will begin supplying 10,000 BPD starting late in 1983 to be processed and sold to the U.S. Air Force for use at domestic air bases. This program is supported by a price guarantee at over \$40/bbl through The Synthetic Fuel Corporation. Union has applied for developing additional modular expansion of its process, on the same financial basis. It is unlikely that action will be taken before results can be evaluated on the 10,000 BPD module which has not yet begun producing.

It is fairly clear to all that the future of the U.S. synthetic fuel program depends on the outlook for oil prices. From the DOE/EIA outlook reported with NEPP-1983 and reviewed in the second chapter of this report, oil prices should remain fairly steady and synthetic fuel development is not encouraged. As mentioned earlier, however, EIA sees world demand for oil increasing enough in the latter part of the century to spur U.S. production of about 100,000 BPD shale oil and 100,000 BPD in coal liquids for electrical generation in year 2000.

As has been discussed, the improved mileage of U.S. automobiles may be beginning a relapse to less economy, a trend which could encourage earlier synthetic fuel production. In contrast, this author believes that a U.S. free market in natural gas, or foreign moves to develop and market natural gas could ease the world demand and price for oil. A myriad of other influences, such as developments in coal processing and combustion discussed in the section just preceeding, could decrease the world demand for oil.

Strictly speaking, however, synthetics need not come only from non-petroleum sources. In a sense, cracked or polymerized gasolines are synthetics, squeezing more gasoline from the barrel of crude than nature provided. In much the same sense, but progressing further, middle distillate fuels such as jet fuel can be produced by cracking or polymerization. These processes have not yet been pursued on the industrial scale because the market has not required it. However, the refining industry has been very active in developing new processes and plants to accept



progressively heavier crude oils and to reduce production of heavier products, such as residual oil, whose markets have been shrinking.

While a major trend in refining may still not be completely confirmed, refiners appear to be on the threshold (or moving past the threshold) of developing catalysts which will (or already do) greatly reduce capital costs as well as processing costs in new plants. The refining industry is reluctant to discuss these prospects because of intense competition. These catalysts appear to be able to: (1) produce products more selectively, reducing the mix of products or maximizing a desired product, (2) act more rapidly and in a single pass, reducing the size and complexity of plant equipment, (3) reduce the costs of catalysts and their use, such as through liquid state or disposable catalysts, (4) accomplish their conversions at lower temperatures and pressures, conserving energy and operating costs and, (5) by operating at less extreme conditions, reduce the strength and cost of refinery vessels required.

If and when these trends are confirmed, superior quality fuels, including jet fuel, should become available at conventional or lower prices. This is an optimistic view of what appears to be going on.

At any rate, use of severe hydrogenation and catalytic processing of various types is likely to increase in the finishing of future fuels, including jet fuels. Being made of literally synthetic molecules, these products will lack most of the impurities and some of the characteristics (such as lubricity) of today's fuels. Since the specifications for today's fuels were built from a purely petroleum base, these synthetics may either add qualities or lack qualities that are universal in natural petroleum fuels.

Consequently, in the fairly near future, one to ten years, it should be desirable to establish a new base of fuel characterization data and specifications. These new specifications should include and describe all the characteristics that various fuels should possess (and exclude) for safe and satisfactory operation.

### Nuclear Power

Nuclear power was discussed briefly in the Impact report and will be mentioned here largely as an updated comment. The state of nuclear power in the United States is a graphic illustration of how public values, or the public's sociological view, can affect the development of an energy source.

As in some other parts of the world, nuclear power has met strong political resistance in the U.S., delaying or cancelling many projects and raising the costs of all. Whereas a few years ago nuclear powerplants exhibited a clear economic advantage over those powered by coal and other fuels, today's environmental,

safeguard and permit problems for nuclear plants have about priced them out of the market.

Indeed, because of these difficulties and delays, and often because of adverse public relations, utility companies who must deal so directly with the public find great difficulty in committing to construction of new nuclear plants. Nuclear specialists are more often heard to observe that they do not expect any more nuclear powerplants to be completed in the U.S. during their lifetimes.

In preparing the data base for NEPP-1983, EIA's projections for nuclear power are founded on plant-by-plant analyses which are updated each year. They note that this year's projections for nuclear are lower than any issued in the past. In addition to some plant slowdowns and cancellation of some plants as much as 30% complete, they note that no new plants have been ordered now for several years. Some of this situation is because of lower electrical demands than expected, financial constraints on utilities, and higher construction costs. But part of these latter two constraints results from the Three Mile Island incident. EIA expects that orders for new nuclear plants will resume in the late 1980s when the demand growth for electricity recovers.

The time and rate at which new plant orders resume will depend strongly on public policies at the time; consequently, EIA notes considerable uncertainty in its forecast. In year 2000, they project a low estimate of 110 gigawatts national nuclear capacity whereas, in case of substantial regulatory reform, the capacity could reach 140 gigawatts. From today's nuclear contribution of 3.5% total U.S. energy, nuclear's share could therefore increase to around 8.5% to 11%.

While the U.S. can afford to be critical of nuclear, having so many other options available, countries such as France and Japan cannot be so restrictive. France has therefore embarked on a policy of developing breeder reactors which will form the backbone of their electrical power system.

While fission nuclear power is controversial in the U.S., fusion power is generally regarded as more benign. Perhaps it enjoys a less definitive place in the future. Probably it is considered less likely to produce undesirable wastes. As pointed out in Impact, although fusion would not present the same disposal problem with spent fuel, the shield material in a fusion plant is likely to become highly radioactive and may, in the long run, constitute as severe a disposal problem as spent fission fuel. Further, many as knowledgeable as Edward Teller have remarked that there is no reason to expect that the capital costs for a fusion plant will be cheaper than for a fission plant. And since the fuel cost in a fission plant is almost negligible in the cost of its electricity, fusion may yield few financial advantages.

Fusion power may be demonstrated satisfactorily within the next few years but, as Teller and others have observed, probably twenty to thirty years of engineering and development will be required before it can contribute significantly to the U.S. energy supply. In the meantime, U.S. nuclear growth will probably be limited to completion of plants which are already under construction. As EIA hopes, and their forecasts assume, existing regulations may be relaxed. Some foreign nuclear programs will no doubt affect the world oil market to a greater extent than will U.S. nuclear activity.

### Renewable Energy Sources

As shown in Chapter 2, U.S. renewable energy supplies less than 8% of the national energy demand, while virtually all of this is from hydroelectric power and from wood, mostly wastes used in the paper and forest products industries. In their forecast to year 2010, the DOE/EIA shows that renewables are just about 8% of domestically-produced energy now, and will increase to about 14% in 2010. The potential for expanding U.S. hydroelectric capacity is very limited.

EIA's projected price increases in oil and gas are expected to stimulate more use of wood, perhaps of large-scale wind, photovoltaic, and possibly solar electrical generating technologies. Even so, renewables are not likely to much affect the larger markets of coal, oil and natural gas in the early part of the next century. Of course, in case of a fine balance of oil demand against world oil production, such as the demand for OPEC oil production EIA forecasts in 1985, a relatively small energy contribution may be successful in staving off oil price increases for a useful time.

As EIA points out, "Major cost and technical feasibility uncertainties affect renewables projections. Factors such as the future cost of competing energy sources, the rate of economic growth, and consumer acceptance of new technologies in the marketplace also affect future renewables supply. The role of renewables in the national energy equation is, therefore, highly uncertain. Renewables could develop from a modest current contribution to a significant energy supply by 2010, depending on factors which are difficult or impossible to quantify at this time."

It should be noted that some energy sources classified as renewables do not really fulfill that definition in the absolute sense. Wood can be grown as a renewable but, if its use is increased substantially, the world's available wood would be depleted--it may already be in decline. Raising wood as a biomass energy crop is not the most efficient use of land and other resources.

Water power is not truly renewable on the long scale of time that coal will be available, for example. Dams and their lakes

inevitably silt up. Unless drastic engineering projects are undertaken, dam sites may be depleted in a hundred years or so.

Geothermal sources may be perpetually heated, but man's use of a geothermal area withdraws the energy faster than it can be replaced by conductivity through rock. So geothermal well steam production depletes at about the same rate as production in an oil well. Geothermal energy production also appropriately enjoys depletion tax allowances. Because they are erroneously viewed as renewable, geothermal installations sometimes improperly receive other financial and tax benefits.

So renewable sources are included here more for completing the national energy picture than for any appreciable effect they are expected to have on national energy, the transportation energy picture, or the future of aviation fuels. On the other hand, some renewable forms of energy may make very useful contributions to the powering of remote aviation navigation and communication facilities, conceivably as large as airport towers or air route traffic control centers. But those contributions will be advantageous to tactical budgets, not to strategic effects on fuel supplies or prices.

#### Geothermal Sources

Like hydroelectric sources, the most efficient way of using geothermal power is by producing electricity, in the case of geothermal sources, from dry steam. But, as with hydroelectric power, one of the greatest problems with geothermal sources is transmission of the electricity to its users. In Iceland or in Klamath Falls, Oregon, where a population is situated virtually on top of a geothermal source, the source's hot water can be used economically for heating and cooling buildings. Otherwise, most of the nation's and the world's relatively economical dry steam geothermal sources, severely limited, are also not conveniently situated.

The Impact report pointed out that the world's most extensive and successful geothermal field has been The Geysers in northern California, which supplies much of the power for San Francisco. Part of that success comes from tax (no windfall profits tax) and other concessions. With additional concessions, other sources in the U.S., including hot-water wells in southern California's Imperial Valley, may become profitable.

While the total U.S. resource of geothermal energy is impressive, DOE estimates that about 20,000 Mw could be brought on line early in the next century, equivalent to about a million barrels of oil a day. The amount is significant, but much of it would be obtained by drilling into dry rock, fracturing it, injecting water through one or more wells, and recovering the heat through another well. The process is so similar to enhanced oil recovery (EOR) that one should consider which is the more economical.

An indication of the status of conventional geothermal energy can be gained by a news release from DOE on August 30, 1983, "Secretary of Energy Don Hodel today announced the approval of \$99.6 million Geothermal Loan Guarantee Application for the Niland Project, located in the California Imperial Valley. This will be the first commercial geothermal powerplant in the United States to operate from hot water sources instead of steam. The total project cost is expected to exceed \$130 million. The project covers the development of a 25,000-kilowatt well field and powerplant, sized to facilitate a later expansion to approximately 49,000 kilowatts."

"...The plant to be constructed will be a dual-flash powerplant based upon a fluid temperature of 525°F and is expected to become operational in early 1986. The Niland loan guarantee is the largest committed under a program begun in 1974 to encourage geothermal development under Public Law 93-410, as amended. The Niland project is expected to stimulate further private sector development of other commercial scale geothermal projects."

During the past two years, some encouraging indications have come from the tremendous source of geopressured brine under the Gulf of Mexico Coast. Where it had been thought initially that these resources looked fantastically large, it then appeared that they were so extensively fractured that the energy was isolated into small units. Since expensive wells are needed to reach the depths as great as 30,000 ft, the costs of tapping these sources appeared discouraging. Additionally, the salt content of the brine tested high and indicated that dissolved natural gas would be restricted. Importantly, energy in the dissolved natural gas was many times greater than in the brine's pressure and temperature.

More recently, brines have been tapped with temperatures of about 500°F, comparable to geothermal wells in the Imperial Valley. But more important, this temperature permits the brine to carry a concentration of natural gas which again begins to look promising.

Where disposal of the vast quantities of brine had recently been regarded as a major obstacle, it has been found that the brine can be economically self-injected into existing shallow brine aquifers, even after second-stage heat extraction. The cost of these wells is still too high to be competitive but, with their heat content now becoming attractive to industry, the picture is definitely improving. Costs of methane from these wells would now run almost competitive with deep-well gas from the Rocky Mountain Overthrust region. The ultimate energy resource from this region may be gargantuan.

As this resource is tested further, the U.S. may find that the Texas-Louisiana area will provide yet another trump card in the energy game.

### Solar Energy

The field of solar energy rightfully includes rain hydroelectric power, wind, waves, and to a large extent, tides. For convenience, the term will be used here for solar insolation, the sun's radiant energy which strikes the earth's surface.

Enough solar projects are now in progress so that fairly reliable economic assessments should be available within the next few years, including solar power towers, photovoltaics, ocean thermal electric conversion (OTEC), salt ponds, and the like.

Probably already we can confidently say that OTEC can be useful where there is a sizeable temperature difference between the local ocean's surface water and the water at depth, combined with a market for the power nearby which does not have access to cheaper electric power. For the U.S., this indicates Hawaii and Puerto Rico are the most attractive sites, although the Johns Hopkins Applied Physics Laboratory steadfastly contends that OTEC ships grazing in tropical waters can produce methanol, ammonia or other transportable forms of energy at competitive costs.

The State of Hawaii has been reviewing a whole myriad of renewable energy possibilities. In addition to being well situated for OTEC, Hawaii has one of the world's best wind sites in the saddle between Mauna Loa and Mauna Kea on the big island. Its geothermal energy may be exploitable, although not conveniently occurring as steam, and its wastes from sugar cane, pineapple and other agriculture may offer attractive sources for methane. Hawaii has some appropriate desert areas for solar power. And it already has landfill that can be tapped for methane gas. It remains to be seen how these options might be exploited and what the costs of energy would be delivered to customers. These examples in Hawaii should be useful to renewable interests in other locales.

The Crude Oil Windfall Profit Tax Act of 1980 provides until December 31, 1985, a 15% nonrefundable tax credit for investments made in renewable resource property. Eligible investments include solar equipment to heat or cool buildings or to supply hot water, or for technology employing wind. In addition, a 10% investment tax credit is offered for biomass property. Approximately 20 states also have tax credit programs, energy grants and other solar investment incentives. It is perhaps ironic that the same act which offers these incentives places one of the strongest deterrents on U.S. domestic oil production, effectively granting an economic incentive to imported oil.

As T. Kemper Brotherton of Reynolds Metals comments in, "Solar Energy & Technology Update," 10th Energy Technology Conference, Washington, March, 1983, "With interest rates coming down, the way it works out is that you can buy a solar system, finance it and not be one cent out-of-pocket. In fact, at the end of the first year, you will be in the neighborhood of \$1000 in-pocket

thanks to the tax credit. How does it work? Fairly simply. There is a 40% tax credit for solar (for residences-Ed.). Forty percent of \$3000 is \$1200. Your financing charges for that first year will be maybe \$300-400. Take that and subtract your fuel savings and supplement it with your tax credit and you are in-pocket with the amounts I indicated. Solar economics for the industry have been fairly dismal. Solar economics for the country and the consumer are pretty good."

Solar installations, particularly domestic systems, are extremely labor intensive systems. In typical systems the labor costs are 60%. This characteristic is a two-edged sword. On the one hand, solar projects are appealing in creating jobs; on the other hand, the high installation costs offset much of the advantage of the renewable energy source.

Another characteristic, particularly for photovoltaic solar arrays, is that site preparation and installation of foundations and supporting structures can easily exceed the electrical system costs. It helps to select a level building site for large systems. One of the important considerations in such a system is to minimize the balance-of-system (BOS) components including foundations, structures, intermodule connections, field wiring, and system grounding. Recent systems have been installed with much improved BOS costs, which some say are becoming competitive with conventional energy sources.

Small photovoltaic installations are already competitive in remote locations, or wherever it is expensive to deliver conventional power. If the cost of PV cells can be reduced by thin-film technology, replacing expensive silicon crystals, photovoltaic installations should increase considerably. PV systems offer one distinct advantage; they can be installed in less than a year. But the installation, BOS, costs will always impose a significant limit on their economic penetration.

Due to the fact that direct insolation systems can only operate effectively for about eight hours a day under the best conditions, solar energy may pay off best for peak shaving in sunny areas where air-conditioning electrical demands are high during the daylight hours.

The world's largest solar photovoltaic system today is three times greater than any other PV system. Built on 20 acres by ARCO Solar, Inc. near Hesperia, California and dedicated in February, 1983, this plant is rated at 340 KWe, enough to supply about 400 average homes in Southern California. Considering that Southern California Edison's 1982 generating capacity was 13,606,833 KWe, this world's largest PV system can contribute about 0.025% of Edison's customer requirements.

For well into the next century, there is little indication that solar energy may displace significant amounts of petroleum in the market.

For a good appreciation of the benefits, problems and the state of the art for large, thermal solar electrical power installations, readers may want to refer to, "Solar Central Receiver Technology Development and Economics - 100 MW Utility Plant Conceptual Engineering Study," by J. R. Roland, Program Manager, Solar Systems, McDonnell Douglas Astronautics Company and K. M. Ross, Senior Research Engineer, Southern California Edison Company, which was presented at the 10th Energy Technology Conference in Washington in March, 1983. Copies are available through Government Institutes, Inc, Rockville, MD 20850.

This report is based on experience from the Solar One power tower and, in addition to the viewpoint of the developer, considers the economics from the viewpoints of a utility-owner, municipal owner, or entrepreneur owner. Briefly, for the entrepreneur owner, a 100 MW plant which begins operation in 1988 would produce power at thirty cents per kwh, as compared to 10-12 cents/kwh for purchased power.

Total annual operating cost of the plant is shown year-by-year through its thirty-year life. Costs at first operation are just under \$200 million, dropping to about \$140 million after 15 years, but then rising more rapidly due to increasing maintenance costs, to reach \$235 million at 30 years. The first year after complete amortization, annual cost is \$225 million, but is increasing at \$15/yr and accelerating because of higher maintenance charges.

With return of original capital uniform over the thirty year plant financial life, in the early years over half of total plant costs are return on capital (interest charges); maintenance costs are only about 10%. At close to half the 30-year period, maintenance costs rise to equal the falling return on capital. At the end of the period, except for miniscule income taxes, the entire plant operating cost is for maintenance.

As mentioned above, initial cost of solar-produced power is about three times the cost of purchased electric power. If purchased power prices are assumed to escalate by 8%/yr, the slower escalating solar plant will match purchased power costs by year 2005, more than half-way through its life. If power costs escalate by 10%, solar catches purchased power in 2000, after 12 years; if escalation is 12%, equality is reached in 1995, after 7 years.

The study concludes that it is feasible to build the plant by 1988, which would produce 98.3 MWe net average output, or 489 kwh annual energy production at a 60% capacity factor and 94.5% availability (excluding meteorological conditions). Utility ownership would result in energy costs that exceed avoided costs, Edison's incremental rate. Of the three ownership alternatives, third-party ownership offers the most promise, although the plant would be subject to federal and state regulation. "The energy tax credit is scheduled to expire in December 1985. Extension or



'grandfathering' is essential to any entrepreneurial ownership of a project of this size."

Thus it can be seen that a facility of this type is not financially feasible to a utility, even with the favorable financial climate that they enjoy. It can be attractive to investors only if energy tax credits are extended through the life of the program. The contrast between these financial benefits, compared with the tax and regulatory burdens laid on fossil fuels, is rather striking.

"To further pursue Edison's corporate objective of having 300MWe of solar capacity by 1990, Edison released a Solar Program Opportunity Announcement (SPOA) on May 3, 1982, to solicit proposals for a third-party ownership of Solar 100; proposals were due September 17, 1982. Edison, therefore hopes to have a minimum of one large solar central receiver by 1990 at or below avoided cost to its ratepayer. This 300MWe goal would increase their current capacity by only 2.2%, or Solar 100 would itself add only 0.73%.

#### Wind Power

Like other forms of energy, wind power has had its ups and downs through history. Invented in Persia, windmills were spread through Europe by the crusaders, but could not compete with water power in colonial America. In the mid 1800s, however, the multi-bladed, automatically regulated, waterpumping windmill played a major part in opening up the West, providing water for people, cattle, and railroad locomotives. Small windmill electric generators were used extensively in the Midwest in the 1920s and 30s, until rural electrification took over. Windmill electrical generation was re-examined as an alternative to oil-fired generation at the time of both world wars, then cheap oil returned.

Now the subject is being reviewed both here and abroad. Although windmill development continued in Europe during long U.S. disinterest, the DOE ("The State of Wind Energy Development Overseas," Louis V. Divone, Director of Solar Electric Technologies, 10th Energy Technology Conference, Washington, March, 1983) considers that the U.S. currently leads in technology for both small and large machines. Divone reports that there are many hundreds of new 20-50kw systems now in use on farms in Denmark.

The International Energy Agency (IEA) has a cooperative agreement on large wind energy systems which requires that members build one or more large systems; Denmark, the U.S., Sweden, Germany, the U.K. and Canada are participating. The largest U.S. installation to date is a DOE-sponsored cluster of three 2.5MW MOD-2 windmills built by Boeing Engineering and Construction Co. at Goldendale, Washington. DOE has in progress a competition to build a single 7.3MW model for operation in 1985. The largest

field of wind machines in the U.S. is 200 windmills of 50kw each at Altamont, California, for a total of 1MW.

All of these are, of course, small in comparison with Solar 100's 100MW, which we have seen is a very small producer in comparison with a large utility company's output. All these renewables have in common the need for investment credits and other financial benefits. In the case of windmills, it is interesting to conjecture how long they may enjoy public favor if they are erected in enough numbers to make a real energy contribution. Already some have been noted critically because of "visual pollution", noise, and interference with television reception.

### World Energy Conference

The World Energy Conference held its triennial meeting at New Delhi, India in September, 1983. It is interesting that none of the some 150 technical papers presented discussed the availability or the estimated quantity for the world's remaining resources of fossil fuels, although previous conferences of 1980 and 1977 expressed deep and detailed concern. Instead, most of the 1983 meetings addressed energy plans of various countries, largely third-world countries, methods for using fossil fuels more efficiently, and particularly methods for employing renewable forms of energy.

This apparently significant shift could be viewed in two ways. A proponent of renewable energy might conclude that renewable sources are the most important matters in world energy today. Others may conclude that most countries of the world now are not alarmed about the prospects for fossil fuel supplies and prices, but are concentrating on how best to use them. One could conclude they are interested in renewables in order to reduce their purchase of foreign energy. Neither this interest nor the energy plans of these countries are likely to affect the world energy market soon but, in the long run, third-world demand for energy growth should outstrip the industrialized nations. For the long run, it is interesting to consider some of the views expressed.

India, for example, notes that their recent growth of electrical power has been phenomenal; it is expected to be strong in the future. Since India has little oil and needs more, Indian electrical generation will grow in hydro, coal and more vigorous future nuclear power. Strong system analyses will have to be maintained to assure equitable distribution of electricity throughout the country, as well as to optimize generating plants between mine-pit locations and population centers.

Many emerging countries like Tanzania are regarding development of virgin hydroelectric power. At the same time, they do not consider it economically feasible to tie much of their population into the electrical grid. Mini-hydro installations may help, particularly in replacing present diesel-powered systems. Other

nations like Yugoslavia, which have developed hydro power intensively in the past, see the end of growth in these resources and need to rely on thermal generation. Some are organizing sophisticated evaluation of their hydroresources to extract maximum benefit.

The USSR smugly notes that it is the only large industrial nation which meets both its energy and materials requirements from within its borders, and expects to maintain development at "outstripping rates." Contrary to earlier reports from the International Institute of Applied Systems Analysis, a Soviet paper contends that they will extensively expand their electrical system, with nuclear power in the European part of the country, with coal, natural gas and oil-gas in eastern regions, and with much more hydropower in Siberia. They will be increasing voltage of electrical transmission lines, and moving to d.c. The paper speaks much of international cooperation, technical assistance abroad, and the "Final Act signed in Helsinki." "On their part, the Soviet power engineers by participating in the Congress are ready to contribute to creation of an atmosphere of cooperation and good will."

Finland and some other countries are very interested in their extensive peat resources, which the U.S. has also begun to recognize. At present, only Finland, the USSR and Ireland use peat to any significant degree, but several other developed and developing countries have started peat programs. Answering Canada's previous questions on using depleted peat bogs, Finland believes cutaway peat bogs can be used for agriculture and forestry, as well as for biomass production.

England is making more sophisticated seismic surveys of its coal resources, also looking at synthetic gas from coal. The Netherlands concludes it will probably not meet the coal goals of the World Coal Study (WOLCOL), but will continue developing coal and oil; she will need to look more toward nuclear power and natural gas. The International Union of Producers and Distributors of Electrical Energy (UNIPED) sees the need for improved management of electrical systems at all levels, using more coal and nuclear power. Many countries reported on nuclear power developments, recalling that the 1980 WEC in Munich surprised the U.S. delegation by strongly supporting and urging increased nuclear development (in spite of popular anti-nuclear demonstrations).

Brazil concludes that sanitary landfills of its largest cities hold good potential for collecting methane. Landfills can be constructed better to improve anaerobic digestion and gas production. Denmark is energetically developing heat pumps. Korea is investigating district heating using waste heat from powerplants. Libya and other desert nations are interested in cogenerating electricity with production of fresh water. Canada concludes that its oil sands production can be improved further to remain competitive in the petroleum market. Augmenting its

SASOL synthetic liquid fuel program with coal, South Africa has begun a major wood gasification program.

The UNESCO secretariat reported on world progress in magnetohydrodynamics, MHD, which is direct production of electricity with a fast-moving stream of plasma in a strong magnetic field. A first-generation MHD family is seen to offer electrical generation efficiencies of 45-50% (compared to 30-33% for steam-coal), while second-generation systems should achieve 55-60%. MHD is currently operable during short periods for electrical peak topping loads; it can go on line quickly and respond very rapidly to load changes. Most of the report deals with details on various MHD design problems. UNESCO concludes 20-200MWe MHD systems will be operating in 1985-86.

In addition to steady emphasis on nuclear power, Japan has been pursuing an intensive "Sunshine Project" to evaluate its potential in solar, geothermal, coal liquids and gasification, and in hydrogen. A parallel effort, "Moonlight" is aimed toward energy conservation.

In a paper, "Development of Renewable/Alternative Resources of Electric Energy," William R. Gould, Chairman and C.E.O., and David J. Fogarty, Executive VP of SoCal Edison, conclude that renewable energy has vast potential, but requires both advances in technology and increase in fuel prices to penetrate the market. Five to ten percent of U.S. energy could be supplied by renewables and alternative sources by 2000, but this goal would require an aggressive R&D and commercialization strategy.

This level of penetration would require 20-40% of the energy increase between now and 2000 must come from renewable resources! Even so, it would not eliminate the need for fossil and nuclear energy. All three, fossil, nuclear and renewables, are needed to stabilize oil prices. Since electricity can be produced from such a variety of sources, it will play a critical part in the development of renewables. Electricity provides the means to "concentrate and transmit the inexhaustible but diffused energy of renewables into compact, versatile and efficient end-uses."

A very large number of the WEC papers are concerned with improving energy uses and processes in various industries. Another group of papers discusses various environmental and sociological energy matters. Still another collection is directed toward improving world cooperation in energy affairs.

# U.S. SYNTHETIC FUELS CORPORATION

## SFC PROJECT SUMMARY

### OCTOBER 1983

PROJECT	OIL SHALE		TAR SANDS/ HEAVY OIL		COAL, LIGNITE & PEAT				WET CARBONIZATION		SOLICITATION	PROJECT STATUS	NEXT CRITICAL MILESTONE <sup>1</sup>	STAFF'S RECOMMENDED CUT OFF DATE							
	TECHNOLOGY	MODIFIED INSITU	GEOMETRICS LOPECO	PARANO DIRECT HEATED	PETROBRAS	CIRCULAR GRATE	STEAMFLOOD	OXYGEN FINEFLOOD	MINING/SOLVENT EXTRACTION	INSITU WET COMBUSTION					UPGRADING	ENTRAINED BED	ENTRAINED BED	FLUID BED	FIXED BED	MOLTEN IRON	INSITU
OIL SHALES	CATHEDRAL BLUFFS																				
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	DEEP MINE																				
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	UNION II																				
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	CHAPARRAL RANCH																				
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TAR SANDS/HEAVY OIL	SUNNYSIDE																				
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	KENTUCKY / TAR SANDS																				
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	FOREST HILLS																				
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	FARMALAND INDUSTRIES																				
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	SLAGGING GASIF CONSORTIUM																				
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	KEYSTONE																				
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Milestones deadlines may be earlier than cut-off dates.

Figure 7-1

Chapter 8Aviation Fuel Conservation

The FAA Office of Environment and Energy plans to hold a symposium on aviation energy conservation in early Spring, 1984.

Chapter 11 of the Impact report contains a basic account of fuel conservation in aviation, including the contributions which have been made and additional contributions which may be made with future developments and systems. Most of the options presented there have now been pursued vigorously. Aircraft operators have available a variety of suggestions and avenues for their consideration. Remaining opportunities for fuel savings lie in two main areas, air traffic control and purchase of new, more fuel-efficient aircraft.

The new, automated ATC system has now gained the strong support from Congress that it needs to assure development. One element of that system is improved aviation wind information. But this information will not be scheduled into the ATC system for at least six to eight years. In the meantime, airlines should investigate how they may improve wind data for flight planning at an earlier time.

It appears that fuel saved by improving wind data should cost at least 5-15 times less than the same amount of fuel saved by buying new, more fuel-efficient engines or aircraft. Equally important, improved wind data will benefit all aircraft using improved flight plans and/or the ATC system, while new aircraft only benefit those who can afford them.

Aviation Weather and ATC

It was shown in Impact that some 12.5% of aircraft fuel consumed in the United States today may be saved with new air traffic control equipment and the Automated Air Traffic Control (ATC) System which it will provide.

About 3% of annual U.S. airline fuel, which is included in the 12.5% estimate cited above, could be saved by improving our knowledge and forecasts of upper-atmosphere winds. This amounts to a saving of about 300 million gallons of fuel per year or, in round numbers, the airlines would save \$300,000,000 per year.

This conclusion has been debated to some extent. Some have contended that the amount likely to be saved in the U.S. is more likely to be 2%, or 200 million gallons, \$200 million. They point out that the basis for the 3% estimate was obtained from flights over the North Atlantic, that winds over the U.S. are not

necessarily similar and, particularly, that cruise ranges over the U.S. are shorter than over the ocean; therefore the effects of adverse winds should be less. Another comment has been that winds aloft may be known better over the U.S. than over the North Atlantic; the opportunity for improvement is therefore less on domestic routes. Penalties for north-south traffic may be less than for east-west traffic.

The argument may be academic. While winds over the U.S. are measured by rawinsonde balloons, their readings are taken only twice a day. Balloon ascensions may require nearly two hours to reach altitude, balloons drift in winds so that consistent spacial reporting is difficult, while slant ranges from the launch site become large and balloon altitudes may be reported inaccurately. After the data are transmitted, collated and resolved into a "nowcast" consistent with balanced meteorological principles, the results are 6-8 hours old. Additional time is required to develop the various forecasts and transmit them to users. The net result is that forecasts are often several hours old. Sometimes a flight plan may be based on forecasts that are 24 hours old, or more.

While the North Atlantic is not covered by a surface weather observation network comparable to that of the U.S., aircraft flying those routes typically are equipped with inertial navigation systems (INS), which can report winds accurately. The 300-million gallon fuel estimate was derived from 20,000 INS-equipped flights made over the North Atlantic. Few aircraft flying domestic routes are INS-equipped because of the existing ground-based navigation system. Consequently, it is truly debatable which area enjoys the better (or the worse) winds-aloft information.

But, in either case, the 300 million gallons lost was computed on the basis of direct winds-aloft vectorial effects on cruise time alone. The effects of unknown or adverse winds on aircraft climbs and descents were not included. Much more important, because the ATC system also does not have good wind data, aircraft are often unnecessarily diverted or delayed due to adverse weather which no longer exists, or has moved in location. Due to this problem of uncertainty, ATC is generally conservative in blocking out flight areas to be avoided. Still, occasionally flights are vectored into unexpected adverse weather conditions, so that ad hoc complaints by crews require ATC to quickly revise their operating patterns. These interruptions and rearrangements can lead to diversions and delays with much more serious effects on fuel economy.

Lastly, the \$300 million estimated is identified only as the direct cost of excess airline fuel burned; critics of the \$300 million figure their estimates on the same basis. But, from a national viewpoint, fuel costs of non-airline aviation deserve equal consideration. Further, total costs to the airlines (delays, missed connections, etc.) considerably exceed their

direct fuel penalties, while the costs to passengers could also be included when considering the net effect. On any basis, poor winds-aloft information and consequent winds-aloft forecasts, are the source of important fuel and dollar losses to U.S. ATC users.

These principles have been recognized in ATC and weather program planning for several years. They have now been formally accepted into the system development plans of both the ATC system and the FAA Weather System Plan, both of which are included in the current official FAA National Airspace System Plan (NASP).

#### Fuel Conservation in the National Airspace System Plan (NASP)

The NASP, first released on January 28, 1982, is a 450-page decision document that spells out in considerable detail specific improvements in facilities and equipment that must be made in the immediate future to meet the projected needs and demands of aviation safety between now and year 2000. The NASP responds to the needs of all elements of the aviation community on a system basis, not individually. Its modernization and automation features are expected to save at least \$43.2 billion in ATC system operating and maintenance costs over the next twenty years. Its savings to the ATC system users should be much more.

According to FAA's, "Summary of the National Airspace System Plan," "The most compelling objective was to improve vital safety services, such as collision avoidance, weather, and landing systems." The system is designed on evolutionary principles, with no technological risks. As various of its subsystems and components are phased into operation, it is important that air traffic control procedures need not change and it is desirable that controllers may not even detect its introduction. No sudden transitions or substitutions will be required. Although improved ATC techniques will be developed and tested long before new equipment is installed, they will not be required immediately. They may be introduced progressively as controllers are trained and experience is gained in active operations.

"The level of automation would be increased to achieve greater productivity, higher capacity, and accomodation of user desires for more fuel-efficient operations. Modernization of FAA's physical plant, already more than 20 years old, would be accomplished through a mixture of selective refurbishment, replacement, and elimination of unneeded facilities."

As an indication of how aviation weather fits into the overall NASP, the major elements of the Plan are briefly outlined:

The fundamental ATCsystem will remain ground-based, although more flexible, and progressively more information will reach air crews.

FAA communications will be improved and better integrated.



The Instrument Landing System (ILS) will be supplemented and then replaced by the Microwave Landing System (MLS). (The MLS will save fuel in approach patterns and airport traffic capacity).

Airport improvements will continue, with emphasis on higher airport traffic capacity.

"Automated and semi-automated weather observation systems will assist personnel in making weather observations at manned facilities and will provide observations from unmanned facilities."

Pilots will have direct access to real-time weather through the Automated Flight Service Station System.

Existing ATC control display systems will be replaced with modern reliable systems capable of higher automation levels.

Terminal automation systems will be upgraded.

In the Automated Flight Service Stations, the quality and efficiency of information will be improved.

ATC management will be modernized with high integration between national and terminal traffic flows.

A ground-based Traffic Alert and Collision Avoidance System (TCAS) will include a low-cost version for general aviation warning alerts, as well as full collision avoidance with instructions for evasive maneuvers, primarily for airline users.

En route primary radar will be phased out in year 2000. Terminal radar with a weather channel will be continued.

Improved weather services for the ATC system will be provided by a new radar. (This is the NEXRAD system under joint development by the NWS, FAA and DOD).

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The major fuel-saving accomplishment of the new, Automated ATC System will be from its increased system capacity, producing fewer flight diversions and delays. In addition to having improved weather (including winds-aloft) real-time and forecast data for operation of the ATC, air crews will have direct access to the same information. This capability will improve pre-flight planning as well as provide for in-flight adjustments as conditions change.

As would be expected, much of the NASP emphasis on weather data improvements is directed toward severe and hazardous weather to improve safety, particularly in airport terminal areas. At the same time, all weather data needed to reduce delays and fuel consumption are formally recognized and included in the plan.

The concern about fuel consumption expressed in many quarters and repeated and emphasized in the Impact report has now been fully accepted. The winds-aloft requirement has been formally defined, approved through the chain of command, and accepted as a discrete development task sheet in the NASP planning document. It is therefore automatically included in all planning and budgetary exercises throughout the life of the parent Automated ATC plan. Concerns for ATC fuel conservation therefore are now confined to assuring that the wind portion of the weather program stays on track, and accelerating the time of its effectiveness as much as possible.

#### FAA Aviation Weather System Plan

FAA's draft weather plan was presented to the public on August 18, 1983. Since that time, comments have been received and the plan has been in modification. The completed issue of the plan is expected to be released before the end of 1983.

The FAA weather plan now fully recognizes, accepts and includes the need for improved winds aloft information for fuel-efficient flight planning and flight operations. It also provides all the requirement definitions, infrastructure and other details needed for collecting, processing, forecasting, updating, and communicating the required weather information.

Specifically, the weather plan establishes that winds aloft data are required by 1992 for the Automated Enroute Air Traffic Control (AERA) subsystem of the ATC, and is included in the formal requirements for AERA. Neither the NASP, the Automated ATC, nor the Aviation Weather plan officially pronounces any requirement for improved upper-air wind data earlier than the 1992 date established for AERA.

Unofficially, however, the National Weather Service (NWS) has accepted the need for better winds-aloft data and has plans in process which may bring about significant improvements by 1988. There is one early experimental, demonstration program which will address this subject directly, on a partial basis. This is the NASA/NWS MERIT project.

#### Minimum Energy Routes Using Interactive Techniques (MERIT)

NASA's MERIT project was conceived by Robert Steinberg of the NASA Lewis Research Center in Cleveland, who made the original study of winds-aloft effects on fuel consumption over the North Atlantic. For the past two years, he has been located at the NWS Environmental Research Laboratory in Boulder, Colorado to manage the MERIT program under joint NASA/NWS sponsorship.

MERIT uses interactive graphics computer techniques for making individual entries into and providing immediate revised weather status reports from a complete national weather model. The model provides both a rebalanced national nowcast and forecasts, as

desired, on the basis of new information. For example, it can provide a new, complete, balanced set of national results after entry of only one new wind vector from a single location.

MERIT's purpose is largely to make use of pilot reports (pireps) from cooperating airlines, many of which can be provided now by automatic in-flight observations and data transmission. During a three-month trial period starting the first of 1984, MERIT will operate at irregular intervals to incorporate the weather information available and assess the effects on airline flight planning and fuel economy.

MERIT will start each operational day essentially with the basic weather picture which is now provided by the NWS, based upon rawinsonde data. But, as information is received from participating airline flights, MERIT will continuously or frequently provide new, balanced nowcasts and forecasts. These airline pirez reports will be supplemented by automated data from four NWS vertical-looking, prototype doppler radars which will continuously measure wind profiles up through jet cruise altitudes from ground stations in Colorado.

These radars provide very valuable inputs by providing complete wind profiles, as contrasted to winds at single altitudes, like the participating airline flights. Further, the radars be operated continuously, and their inputs are planned to be incorporated essentially at half-hour intervals. The resulting MERIT nowcasts and forecasts will be used by the participating airlines and Aeronautical Radio Inc. (ARINC, the airlines' cooperative communication network) and the FAA Denver Air Route Traffic Control Center (ARTCC). As may be seen, its effectiveness will be limited by the number of radars and the number of pirez aircraft in the test.

There are approximately 70 rawinsonde stations in the U.S. Consistent with NWS analysis and forecast methods, national nowcasts and forecasts are predicated on a macroscale grid with nodes at essentially 1500 km, about a hundred miles. This NWS system presents a weather picture which is satisfactory for national surface weather purposes, particularly when supplemented by live ground observation stations. But weather phenomena pertinent to aircraft operation, such as the jet stream, thunderstorms, icing, clouds, fog, etc. occur at the mesoscale level, in terms of tens of kms, a few miles. Whereas the macroscale weather reports and forecasts can indicate the general likelihood of weather conditions important to aviation, a macroscale system cannot give discrete information important to aviation. Further, until the NWS can collect data consistent with mesoscale operations, forecasts made on a finer grid, but from mesoscale observed data, would offer little improvement.

The MERIT model is constructed and operates on the mesoscale, not only to provide the detail of output desired, but also to retain the mesoscale detail of reports it will receive from both pirez

and the Colorado profiler radars. MERIT is built upon the same macroscale basic NWS national weather picture, but adds local enhancements from the extra inputs it receives, largely from pireps, but also from the local radars and from satellites. As mentioned above, MERIT can respond to any single new input, inserted anywhere into the national grid.

After its operation scheduled for three months, the results of MERIT will be evaluated, but the system is not scheduled to remain in operation. NASA may devise plans for a continuing system or from an improved system growing out of MERIT. But it is not within their mission, nor would NASA intend to implement a system operating after MERIT.

The NWS is, of course, intimately involved in the entire MERIT process and not only supplies, but developed the vertical-looking profiler radars which MERIT will use. NWS would like to replace their rawinsonde observations with profiler radars or other modern equipment. While the number of observation locations would not necessarily be the same as for rawinsondes, neither would they be as numerous as the difference between a macroscale and a mesoscale grid. Their frequent-recording capability is only one asset which permits them to fulfill mesoscale requirements smaller, reasonable numbers of stations. In a modernized system, MERIT's capability for using pireps may be retained. Both NASA and NWS studies indicate that a new network of radar profilers or comparable instruments, would be much cheaper to operate than the rawinsondes; their capital costs would be returned in a very few years.

Unofficially, it appears now that with present commitments and within budgetary priorities, the NWS may be able to improve this weather observation situation starting in about 1988.

If airlines or others are interested in pursuing the possibility of continuing an effort similar to MERIT, or build upon it to bridge the gap until 1988 or 1992, they should follow the MERIT operation closely.

#### Aircraft Improvement Potential

In Chapter 11, the Impact report included a rather complete, but general outline of the potential for improving transport aircraft fuel efficiency for the next one to two generations, to year 2000. The first of these new generations, the Boeing 767, is just coming into service, providing fuel savings as high as 30-40% over the equipment it will replace. Both the McDonnell Douglas DC9-80 and the Boeing 757 are not quite as completely new as the B767, but both will realize fuel savings nearly as great. Aircraft design teams expect that subsequent generations of aircraft will continue to provide comparable percentage savings in the remaining fuel required. They see no end of potential for saving aircraft fuel in the future.

For transport aircraft, little can be added now to material presented in the Impact report. Indications of future fuel efficiency improvements reported there continue to look valid. NASA is cautiously encouraged about the prospects for some natural laminar flow drag reduction, particularly as composite-structure wings are introduced. Laminar layer stabilization by cryogenic cooling still needs basic investigation. NASA's studies of total airplane system design concepts continue to appear promising, starting with their twin-fuselage concepts.

Future transports and other aircraft may or may not use twin fuselages. Military aircraft are likely to use some of these newer approaches before the next generation of transports. The twin fuselage probably represents just a first look, and total integration may evolve through other concepts. These developments are just possible manifestations of the improvements that designers consider achievable in the future. What is important is that the improvement process appears sound. The chances are that designs will appear rather conventional, at least for the next generation following the B767, but they will provide significant additional fuel savings.

Since the Aeronautics and Astronautics issue of February, 1982, which was referenced liberally in the Impact report, NASA's Langley Research Center has looked closer at improved design applications for general-aviation type aircraft. Considerable material is included in a briefing brochure, "Status Report on Technology Needs and Opportunities for General Aviation and Commuter Aircraft from a Systems Point-of-View," August 15, 1983. Although the brochure is aimed at all pertinent technology, its discussions of aircraft drag and weight apply directly to fuel conservation.

As mentioned in Impact, a 1% improvement in drag provides essentially a 1% improvement in fuel consumption. A 5% reduction in weight usually produces approximately a 1% reduction in fuel burned. However, if the weight saving is large and the airplane can be redesigned for a smaller engine, etc., the effect is greater.

Past experience has shown that it is very difficult to reduce aircraft drag through skin-friction reduction. Skin friction accounts for about 30-50% of the aerodynamic drag of an aircraft in cruise. Laminar flow at the skin produces much less friction than turbulent flow. Laminar flow control (LFC) involves either removing air as it loses energy from friction along the skin, or injecting more air to raise the energy layer in the boundary layer and delay its transition into turbulent flow.

NASA points out that new small aircraft may enjoy an advantage over transport-sized aircraft. New, plastic construction of wing surfaces, as well as other aircraft components, provides an excellent opportunity for holding close construction tolerances.

Plastic surfaces are smooth and fair, usually unstudded with rivets, skin joints and other discontinuities. Equally important, plastic components are rigid, so that they do not wrinkle or dishpan under load, thereby presenting a smooth surface under all flight loads and conditions. Smaller aircraft also fly at lower Reynolds numbers, where the friction drag coefficient is higher, providing a greater potential for saving through natural laminar flow; the boundary layer is also not quite so sensitive as it is at higher values of Reynolds number.

Conventional airfoil contours can benefit by using smooth and rigid plastic construction. Additionally, however, the airfoil can be designed to naturally extend the region of laminar flow, which could not be accomplished with standard metal construction. Fig.8-1 shows that at lift coefficients above 0.5, wing section drag coefficients can be decreased by as much as 15-50%. Happily, this effect increases at higher lift coefficients, so in takeoff and climb, the power required may be appreciably decreased. Also with improved drag at higher lift coefficients, aircraft should be able to cruise at higher altitude, for further fuel economy.

NASA points out that, for a wing with sustained laminar flow, the wing stall is steeper, requiring more careful design of the wing's flap or of the aircraft's flight control system.

From flight tests with carefully contoured sections on an existing wing (Bellanca Skyrocket), NASA found a wing drag reduction of 25%.

NASA believes future small engine designs could realize up to 30% improvement in their specific fuel consumption and 45% decrease in engine weight. About 20% fuel consumption improvement can be obtained with an advanced turboprop by improving various component efficiencies, such as more efficient combustion and turbocompounding. Some advanced cycles which use a stratified charge would also be able to operate with broader-spec fuels. Advanced cooling methods can reduce engine losses and, through smaller cooling-air requirements, also reduce aircraft drag.

Engine weight may be reduced by more turbocompounding, higher internal pressures, higher RPMs, and advanced materials such as titanium. Composite materials may be used in some applications, while there is also opportunity for reducing internal engine friction. Lighter engines will reduce installation drag and decrease the overall aircraft weight, for either better performance, reduced fuel consumption, or some of both.

NASA notes that conventional riveted skin-stringer aluminum aircraft structure has been so highly developed that it is difficult to introduce new aircraft materials or fabrication processes. Investment in manufacturing tools and equipment also contributes to the problems and costs of making changes. But there is real opportunity for fuel savings of 4-17%, weight

reductions of 10-20%, initial cost reductions of 4-16%, and direct operating cost savings of 5-15% by using bonded structures and other new techniques. These designs can also provide reduced maintenance and probably improved crash safety.

NASA emphasizes that the potential weight reductions offered by improved powerplants or structures should be valuable. For a 19-passenger commuter aircraft on a 100-mile flight, a 10% reduction in empty weight translates to a 7% reduction in gross weight and a 6% reduction in required engine power and wing area. This produces a 5% decrease in block fuel used and a 6.5% decrease in direct operating cost. So, saving one pound of the aircraft empty weight (0.01% of empty weight) would save \$87 in aircraft operating cost over one year or \$1300 per aircraft over a 15-year period.

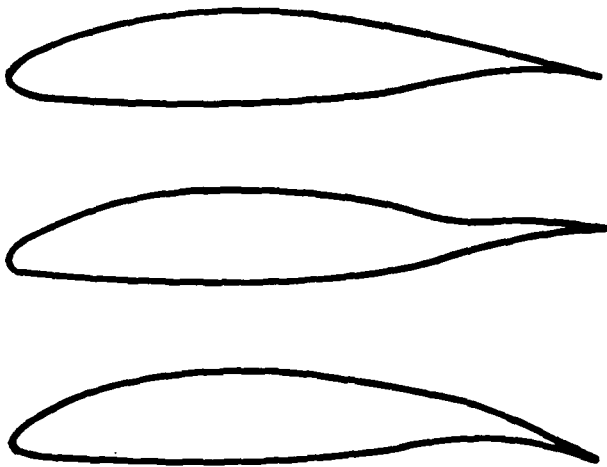
NASA points out that the Learfan 2100 and the new AVTEK 400, a competitive design which will fly in 1984, are examples of new composite-structure design potential; wing, fuselage, tail and control surfaces are all graphite/epoxy. The Cessna Citation III uses graphite/epoxy and Kevlar/epoxy for structures which are critical in weight or stiffness. Gates Learjet is considering using composite structure technology to reduce wing weight on the Longhorn 55.

NASA also notes that small transport aircraft systems, particularly the avionics, or communication and navigation equipment, can be improved in reliability and weight. Aircraft control systems could be improved with fly-by-wire or fly-by-light design, although industry is reluctant to move away from mechanical/cable systems. With improved flight controls, avionics and icing protection systems, NASA expects the potential fuel savings could be 10-15%, for DOC savings of 6-10%.

This NASA brochure goes on to outline technology developments needed to obtain all these various improvements. It also proposes the general research program which will be required. NASA is concerned that aircraft for commuter service do not use the modern technology of today's major airline aircraft, while nearly all commuter equipment with passenger capacities over 20 are manufactured abroad, although using U.S.-manufactured engines.

## Natural Laminar Flow Airfoil Design

NL(S)-0715F  
Design Including Flap



Wind Tunnel Test Comparison

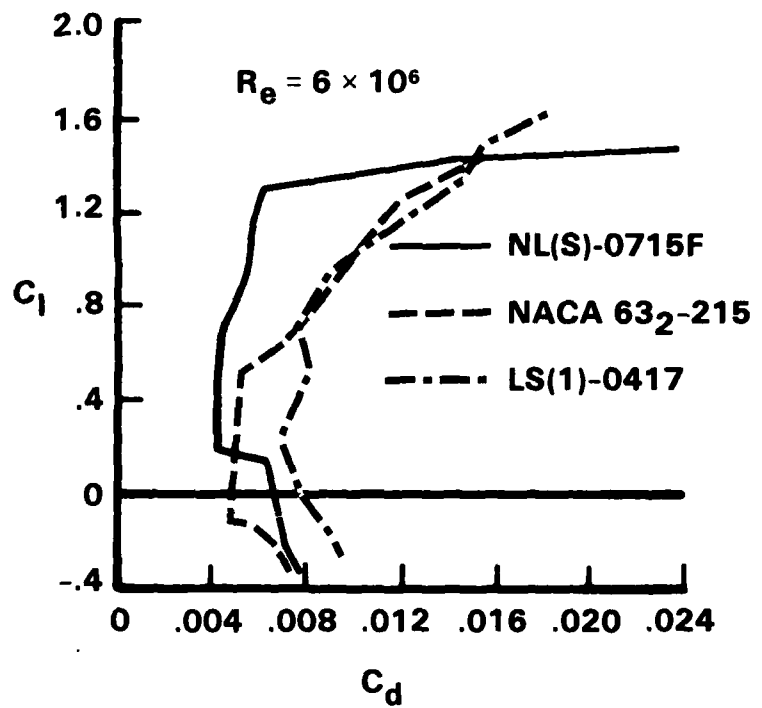


Figure 8-1



CHAPTER 9Fuel EmergenciesProbability of Disruption

As reported in the Impact report, an informal poll of some ten foreign-affairs analysts in the summer of 1982 concluded that they all agreed the probability of a serious disruption in free-world crude oil deliveries was about one in five years, or at least two or more in any ten-year period, through the remainder of this century. However, the Georgetown Center of Strategic and International Studies (CSIS) has observed that, while they agree with this opinion, they are certain it is not unanimous among the community of foreign-affairs analysts.

FAA asked CSIS to convene a forum of some thirty or so recognized analysts in this field, a fair representation of all opinions likely to have been developed on the subject, for an active discussion and reporting of both the range of opinion (on the probability of a disruption) and the distribution of opinion. After CSIS had begun active planning for the meeting in July, 1983, FAA was unable to sign the contract it had proposed early enough to permit the conference to be held at that time. Fortunately, the Department of Defense, through the Defense Fuels Supply Center, has made the contract with CSIS and the forum will be held on November 10, 1983.

Faced with the decision now whether to delay this report until those results are available, it is concluded that other material in this report should be made available without further delay. It is with regret, therefore, that this chapter goes to press incomplete and with such an early prospect for its most valuable input. It is hoped that a preliminary indication of the CSIS meeting may be inserted in Chapter 1, SUMMARY.

In the meantime since the Impact report, while there has been no disruption, the threat has certainly not subsided. All the internal strifes and risks among the Arab states and between Islamic sects appear to have remained as volatile, perhaps more strained due to further, unresolved extrapolation.

The Iran-Iraq war shows no signs of conclusion, while delivery of French Super Entendard bombers to Iraq has sharpened the conflict to nearly a stage of crisis. The Ayatollah Khomeini threatens to retaliate for any Entendard strike against oil installations or other Iranian interests by shutting off the Strait of Hormuz to all oil traffic. Don Oberdorfer reports in The Washington Post of October 9, 1983, "Iraq to Use French Jets in Gulf War." "The Iraqi decision to change the tempo and direction of the war, believed to have been made in Baghdad last summer, was

transmitted to Washington officials in clear and forceful terms in recent weeks, according to State Department sources."

"All the analysts contacted agreed that the real impact of a new reduction in the flow of crude oil from the Persian Gulf could be largely if not totally offset by other countries outside the Arab world. Many are producing at far less than capacity because demand is low. 'If Iraq and Iran managed to halt each other's oil exports entirely, the world would lose about 2.5 million barrels of oil a day,' an official at a major U.S. oil company said."

Such a move precipitates just the kind of disruption that the CSIS forum is designed to assess, and there is no purpose here in speculating further pending the CSIS result.

The CSIS conference plans to review four facets of the subject: "A Retrospective Review", "Current Scenarios for Oil Supply Disruptions", "Assessment of Probabilities for Oil Supply Disruptions", and "U.S. Policy Response". This will leave for future review the effect of oil disruptions on the U.S. economy and aviation.

#### U.S. Energy Response to Crude Oil Disruptions

The United States is one of 21 members in The International Energy Agency (IEA), which is affiliated with the Organization for Economic Cooperation and Development (OECD), in turn, related to NATO (North Atlantic Treaty Organization). Other members include: Australia, Austria, Belgium, Canada, Denmark, Germany, Greece, Ireland, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, and the United Kingdom; although IEA headquarters are in Paris, France is conspicuous by its absence. While agreements under the IEA officially are binding as international treaties, there has been some debate as to how various members, including the U.S., will respond in the event of an actual oil crisis.

Some believe that both the U.S. and other countries are likely to act in their best separate economic interests at the time. Others point out that, realistically, the U.S. and the other nations already have strong enough economic dependency so that it is not prudent for countries to act unilaterally. Unilateral action would not only deprive important parts of the joint economy, but would precipitate a chaotic price situation which would injure all members. Perhaps it is safe to conclude that the course will not be clearly set in any direction. In fact, the debate as to what is happening and what did happen may continue during and after a crisis.

When administrative machinery has been set in place ahead of time, however, there is strong likelihood that the machinery will begin to operate in accordance with established policies and procedures unless intentional countermeasures are introduced

during the response process. If this premise is accepted, there are still two major questions remaining about response to the IEA treaty. First, will the emergency be declared and recognized by IEA and its individual members; will the U.S. declare the IEA agreement is invoked as soon as advised by IEA? Second, how can the U.S. pursue its domestic policy of a free, governmentally uncontrolled energy market and, at the same time, comply with IEA allocation agreements?

Some indications toward answers to these questions have been generated during a recent IEA exercise, but many more questions appear to have been raised during the process than have been laid to rest. This exercise was IEA's Allocation System Test Four, AST-4.

#### The IEA AST-4 Exercise

In the past, IEA has held three Allocation System Tests, AST-3 having been held in October and November of 1980. Prior to AST-4, however, these tests have been largely tests of contacts and communications within the IEA staff structure and their primary national counterparts. AST-4 was established as the first test in which each nation was requested to analyze its energy and fuel operations (largely petroleum supply and refining) during the exercise, and to respond with oil requests and sharing offers to IEA for clearing among nations. In addition, it would be the first test in which oil price response to the exercise would be tracked. For those outside the IEA organizational network, it was the first real test of IEA agreements.

According to DOE, "The primary objective of AST-4 was to train IEA industry and government personnel in the implementation of the oil allocation system and to assess the effectiveness of national emergency management programs."

Planning and some preliminary communications preparations for the test began in December, 1982. It is very important to note that all nations agreed to use world oil data from 1981, as being the latest which had been completely reported and evaluated. The exercise would officially begin with notification at the first of May, 1983 from IEA, signalling that the exercise was in effect and advising each country as to the amount of its delivery curtailment. The test ran, twenty-four hours a day, through the months of May and June. Each country was expected to model its internal energy supplies and demands, resolve its activity in fuel switching, allocations, rationing, or other actions.

Also for the first time, AST-4 would consider the mutual effects of petroleum with electricity, coal, and natural gas within each country. Presumably, if the test had run longer, changes in international shipments of coal could have been evaluated. The exercise was concluded at the end of June due to IEA fund limitations. During the test period, however, it was planned to

simulate a second disruption near the first of June, although it was not expected that effects of this second perturbation would have tracked entirely through the international supply system before the end of the test.

Within the United States, the Department of Energy, in collaboration with the State Department, fulfilled its direct responsibility as contact with IEA, as well as for all communications and policy decisions needed to be made within the U.S. Ten individual U.S. states and numerous oil companies and distributors, as well as other U.S. energy organizations, actively participated in the tests. DOE used its extensive energy computer models to track flows of supplies, development of requirements, and price responses during the exercise. In turn, by its direct contact with IEA HQ in Paris, and through a comprehensive report each day, DOE offered supplies available in the U.S. for sharing with IEA members or, if the occasion arose, advised if the U.S. needed supplies from other members.

Within the U.S., DOE maintained communication with all AST-4 participants, as well as a computer-controlled message bank which could be accessed through direct telephone-computer link at any time. No energy consumers (other than the ten U.S. states) took part in the exercise. Effectively, distributors decided what the customers' needs and responses would be; these requirements were then entered into the DOE models as the test progressed. Various other governmental departments, such as DOT, were alerted to stand by so that they could advise if any major departmental policy question arose. Nothing transpired which required DOT participation during the test. FAA learned of the test unofficially but, by request, was invited to attend the pre-test and post-test meetings. FAA recorded all the messages within the communications bank.

Various offices within DOE were brought into the exercise as required for appropriate energy inputs or decisions, and the Secretary of Energy was available throughout, to be contacted on the decision of the DOE office conducting the test, the Deputy Assistant Secretary for Energy Emergencies, who reported to the Assistant Secretary, Environmental Protection, Safety and Emergency Preparedness.

AST-4 began as scheduled at the first of May, when IEA advised that an 8 million BPD disruption had been sustained. The U.S. direct share of this disruption was one million BPD. The test appeared to run smoothly, with no interruptions or back-tracking.

But results of AST-4 were controversial. DOE spokesmen concluded the results were highly successful, since their main concern had been with communications, rapid transmission of developments, timely analysis and response to energy shortages, close contact with IEA, and response to all IEA hypothetical transfers of petroleum among member states. To that extent, satisfaction was fully justified; the exercise operated smoothly, in real time,

while responses appeared to be fully logical and reasonable.

U.S. internal policy was to invoke no regulations, no allocation, and no federal action. The free market was not only to prevail, it was to remain the sole basis for establishing trade agreements and flows of supplies. The price of fuel would find its level in accordance with unregulated market response. The U.S. did not propose to draw on the Strategic Petroleum Reserve (SPR) unless required by some serious supply dislocation on the national scale.

Everything went smoothly and, following the initial disruption notice from IEA, within a couple of days the hypothetical price of crude oil rose to \$98/bbl. Under that impetus, trades continued to be made and oil supplies continued to flow without interruption or shortages. DOE concluded the affair was a success.

But some of the ten participating U.S. states and some members of Congress have concluded the \$98/bbl price for crude oil would impose disastrous inflation and other penalties on the economy. It is understood the Secretary of Energy was displeased that these trends were not brought to his attention until the price rise to \$98/bbl had already occurred. The Netherlands and other allies complained that, while they received the hypothetical allocations they required, their governments could not accept the higher prices their oil distributors negotiated by proxy. More particularly, the Netherlands felt the U.S. SPR was fundamental to the U.S. emergency mechanism and that it should have been brought into play to prevent the price rise. And especially, the Netherlands regarded the U.S. policy of adhering to a free market during a major crude oil disruption as incompatible with the entire concept of control and allocation, as established under the IEA agreement.

Although these issues have now fully surfaced in the media and have been raised within the Congress, the press of other events so far has prevented their active debate. In Energy matters, the Administration's proposed amendments to the Gas Policy Act of 1978 are more urgent. But it may be expected that, as the federal process of budgetary hearings grinds through its cycle, these unresolved AST-4 matters should be fully scrutinized.

AST-4 leaves several U.S. issues undecided. The Administration has emphasized repeatedly that it fully intends free market forces will determine market action during emergencies. It is apparent that this policy had been intended both philosophically and literally. Administration spokesmen have stressed that federal regulation of energy will be withheld until there is some very serious dislocation of the economy. AST-4 has probably provided the basis for more detailed definition and consideration of how serious a dislocation must be before the SPR is invoked. Also, AST-4 raises the question of whether a major dislocation must actually have occurred before the Administration will act,

or whether the onset of a calamity may be anticipated. There may be a vast array of ramifications to these questions.

It must be remembered that AST-4 was run on the basis of the 1981 world energy situation. Energy demand and supply balances were considerably different in 1981 than when AST-4 was run in 1983. As discussed in Chapter 2, and particularly as shown in Fig.2-2, the crude oil market price response to a rise in market demand is critically dependent on the supply/demand balance at the particular time, as well as on the idle production capability (such as OPEC's) at the same time. Whenever demand pushes request for OPEC oil above 80% of OPEC production capacity, we should expect a rise in world oil prices. As pointed out in Chapter 2, this price rise may easily be 100% when the demand for OPEC production reaches 95% of capacity. Conceptually, the price of oil would approach infinity as the demand for OPEC oil approaches 100%.

But these are only indications. Oil market responses are unlikely to be so precise. New circumstances are likely to affect the demand/supply/price balance each time a major market stimulus occurs. If Fig.2-2 can be believed, a very small change in demand could have held the AST-4 price to \$50/ bbl, or could have shot it up to \$200/bbl. We know from 1979-80 that local stockpiling and panic buying can double oil prices when there is no real oil shortage. So, does a \$98/bbl hypothetical price for oil in the 1981 market mean anything in 1983? Practically, probably not. Politically, probably it does.

As pointed out in The Secretary's Annual Report to Congress, DOE, September, 1983, "The goal of national energy policy is to foster an adequate supply of energy at reasonable costs--a goal on which nearly everyone can agree. However, because judgments about what constitutes 'adequate' or 'reasonable' vary over time and with circumstances, energy policy does not attempt to define these terms precisely."

Already it is understood that the line of responsibility of the DOE offices for Energy Emergencies and for Strategic Petroleum Reserves has been revised within DOE. If another exercise takes place or an actual emergency occurs while Secretary Model is in office, it is probable that he will be kept closely advised of the exercise's progress and that he will be prepared to make early policy decisions. It is entirely possible that, if congressional hearings are held on the AST-4 exercise, on DOE emergency preparedness and/or on the SPR before the next emergency, real or hypothetical, additional factors will be examined which have not yet been discussed nor recognized. It should be a healthy debate, while all participants and spectators should learn a great deal.

Finally, if the budgetary reviews of AST-4 should happen to bog down, it is unlikely that our IEA foreign partners will languish for long. These are issues which will be resolved; if not by

plans and agreements, then later in the heat of a real emergency.

#### The Strategic Petroleum Reserve (SPR)

The Impact report's Chapter 12 described the basic, general working mechanics of the SPR. Although a number of SPR studies and plans have been completed since June, 1982, there have been no significant departures from the basic SPR plan nor its system framework.

The Administration has continued to fill our SPR as the keystone to its emergency energy policy. The past, Carter administration had encountered much difficulty in attempting to fill the SPR, triggering a mandate from Congress (the Energy Emergency Preparedness Act of 1982 requires a minimum fill rate of 300,000 BPD, providing funds are available). The Reagan Administration has energetically pursued this project. Perhaps helped by events, the Administration nevertheless quickly concluded an agreement with Mexico to assure that the SPR could be filled as fast as storage space becomes available and the U.S. budget can permit purchases.

As will be noted from the fill rate chart of Impact, Fig.12-3, from late 1982 through 1985, the SPR fill rate is limited by available oil storage capacity. This Administration has even discussed buying oil faster than SPR storage can be expanded, keeping the oil in temporary storage above ground until additional salt cavern volume can be leached out. The rate at which the SPR should be filled necessarily conflicts current events with forecasts for oil prices, with interest rates, the state of the economy, the cost of above-ground storage, the federal debt situation, the probability of crude oil disruption, the state of private petroleum stocks, the economic situations with other IEA members, and so on.

But today's arguments about filling the SPR are a matter of detail. The present policy for completing the fill is well established and supported, while the actual filling schedule is proceeding very well.

The SPR stood at almost 300 million barrels (293.8) at the end of 1983, at 350 million by the end of August, 1983, passed 365 million in the middle of October, and will level off temporarily at 400 million before the end of 1984. These achievements are all consistent with plans shown earlier in Fig.12-3 of Impact and, in fact, DOE purchased more oil in 1982 than provided for in the 1983 budget submission. As also shown by Fig.12-3 of Impact, in 1984-85 there is a necessary one-year hiatus in further filling while more salt-cavern space is leached. By 1986, we should resume filling at the rate of 300,000 BPD, a rate which has been achieved in the past, and which is covered by our purchase agreement with Mexico.

Our final goal of 750 million bbl should be completed in 1989-90.

Actually, the original SPR enabling legislation provides for a full billion barrels of eventual reserve. However, it has been tacitly agreed by all parties that 750 million barrels is an appropriate point at which to stop and assess the entire national and international energy situations before the final 250 million barrels is committed. It may be significant that at the time the SPR was created, it was anticipated that the U.S. would now be importing between 8 and 11 million barrels of oil a day. While our net imports ran at a rate below 3 MBD for a short time earlier in 1983, at the end of October we were importing just over 5 million barrels a day, including 400,000 BPD imported for filling the SPR.

As the Secretary's report to Congress points out, "It is thus apparent that the magnitude of insurance policy called for 5 or 6 years ago no longer is required, especially in light of the need to control Federal expenditures. Therefore, on December 1, 1982, the President submitted to Congress a finding that it would not be in the national interest to fill the reserve at a rate of 300,000 barrels per day in 1983." This could presage the possibility that the 300,000 BPD rate will not be fully resumed in 1986. Even so, any reduction that is imposed is now unlikely to affect the total impact of the SPR to any appreciable degree. The SPR is already a significant factor in the international petroleum market.

#### Use of the SPR

Present policy for drawing down the SPR was also presented to the Congress by the same December 1, 1982 plan. The President will determine when releases from the SPR will be made.

The present SPR drawdown capacity is 1.7 million barrels per day, consistent with the plan at the time of the Impact report. Drawdown capacity will increase to more than 3.5 MBD on completion of Phase II, also as shown in Fig.12-4. At the end of Phase III, with 750 million barrels in storage, the SPR will be capable of delivering almost 4.5 million barrels per day, then effectively one of the world's largest oil producers.

As has been anticipated, the method for selling oil from the SPR is planned to be by price-competitive sales. Quantities defined by the President will be put up for auction. The DOE believes participation in these auctions should be as wide as possible. Bids from responsible foreign interests will be entertained along with those from U.S. organizations. Further, there will be no restrictions imposed on use of the oil bought. Critics contend that this open auction procedure, with uncontrolled use, could lead to speculation and further price instabilities.

The Administration counters with the view that a free market has natural methods for discouraging speculation and other adverse practices. Anyone attempting to control or corner the market could as easily end up with a loss as with a profit. On the



other hand, if speculators do bid up SPR sales prices, as seller at higher prices, the Government will be the beneficiary.

As a measure of last resort, the "new" plan (December, 1982) permits distribution of no more than 10% of the volume of oil in the SPR released in any month to any specified buyer or class of buyers.

There have been a variety of suggestions of how emergency sales should be made from the SPR; the DOE staff has evaluated many of these ideas. One of the more prominent schemes has been to sell SPR futures, for deliveries to be available when emergency conditions have been pronounced. This proposal suggests that possession of future rights may permit potential users to delay delivery until they actually need the stock, thereby cutting down the likelihood of panic or premature deliveries. Some comment that such a provision could either delay a crisis or eliminate small ones. Future delivery rights would be sold and resold on the market like any other commodity holdings. One of the disadvantages of the scheme is that, if sales are made at times of market tranquility, the Government would suffer through lower sales prices. Since much of the SPR was bought before OPEC lowered its price to \$29/bbl, the Government would stand a stiff loss by selling futures today.

A desire to maximize Government profit through SPR sales is almost self-defeating. If, to protect its cost or to seek a profit for the federal budget, the Government delays SPR sales until oil prices rise substantially, the economy may suffer seriously before the SPR can adequately stem the price rise. The result could be another round of inflation, recession and unemployment.

These matters are unlikely to be debated in the current session of congress because of higher priority matters, including the hope of reaching a resolution on natural gas. In the next session of the congress, and during budget hearings by various committees, they are certain to be surfaced and examined. Today we are operating under the very simple policy of free market forces, during an emergency as well as during normal business conditions. It is probable that this simplicity will be modified by future legislative action.

The aviation community probably cannot anticipate what the outcome of these future debates will be, or whether the outcome will be beneficial or detrimental to aviation.

#### The 1983 National Energy Policy Plan - NEPP-1983

##### National Energy Policy

The essence of NEPP-1983 is to provide, "...an adequate supply of energy at reasonable costs..." This requires "...a flexible energy system that avoids undue dependence on any single source

of supply and...freedom of choice."

"...reasonable costs' suggests economic efficiency and prices that permit residential users to use energy for heating and cooking without being required to alter their lifestyles, and it suggests that commercial and industrial users will be able to consume energy without reducing their competitiveness in domestic and international markets."

The NEPP proposes to:

"...minimize federal control and involvement..." and to

"...promote a balanced and mixed energy resource system..."

Minimum federal intervention does not assume elimination of all government activities. "...protecting the environment, maintaining health and safety standards, and improving energy security are appropriate government responsibilities."

For a balanced energy system: "...fossil fuels, solar and other renewables, nuclear energy, and conservation combine to meet the Nation's energy requirements."

NEPP points out federal actions have included removal of allocation and price controls on oil, regulations governing many other forms of energy have been removed, the Nuclear Waste Policy act of 1982, and the Department of the Interior has substantially revised procedures "...for leasing federal lands and the Outer Continental Shelf to ensure that the Nation's abundant energy resources are made available for exploration and development in accordance with strict environmental rules."

Further, "The amount of oil in the U.S. Strategic Petroleum Reserve has tripled." There have been Presidential policy statements on nuclear non-proliferation, nuclear energy, and coal exports.

Federal R&D programs now emphasize basic and applied areas that cannot be carried out by private industry. Large-scale demonstration and commercialization activities have been eliminated from the federal program (some transferred to the U.S. Synthetic Fuels Corporation-Ed). Total federal expenditures for R&D have been decreased while funding for basic science research has been increased.

"...three areas of energy programs and actions are particularly important."

(1) "Energy conservation actions are often cheaper and easier to undertake and, as experience shows, often make good business sense."

(2) "Federal research and development programs in areas such as

solar energy, conservation technologies, enhanced recovery techniques, magnetic fusion, breeder technology, and synthetic fuels are useful precursors to commercialization of new fuels and technologies needed to foster a balanced and mixed energy resource system over the long term."

(3) "Federal programs that focus directly on our preparedness for an energy emergency include the development and continued expansion of the Strategic Petroleum Reserve (SPR) and maintenance of the Naval Petroleum Reserve (NPR)."

"Domestic energy security is enhanced by a range of other federal energy programs, including oil price deregulation; regulatory reform efforts in natural gas pricing and nuclear licensing; leasing programs for federal lands and the Outer Continental Shelf; enhanced energy trade; and expanded research and development, including cooperative international research efforts."

"Two current legislative initiatives are particularly important--"

"The first...is removal of controls on natural gas wellhead prices. Earlier this year, the administration proposed the Natural Gas Consumer Regulatory Reform Amendments of 1983."

"The second legislative initiative...is...to reform the nuclear licensing and regulatory process."

#### NEPP-1983 Comments on Energy Sources:

"...decontrol of all natural gas prices at the wellhead by a certain date is critically important to achieving a decrease in natural gas prices after legislation is enacted and to maintaining gas prices at a level that is lower than would result from continued government controls."

"Technologies that convert renewable resources into usable forms of energy, such as active and passive solar heating and cooling; photovoltaics; wind, biomass, and ocean thermal conversion; and geothermal energy systems offer a vast potential source of energy supply...For many renewable technologies, however, advances still must be made before economically viable systems will be available to produce energy in major direct thermal applications and bulk electricity supply or to meet requirements for liquid and gaseous fuels."

On magnetic fusion, "Before it will have any practical application, however, numerous technical and basic scientific uncertainties that are being addressed by federal research must be overcome."

"In the case of oil and gas, long-term production from conventional sources is likely to decline, certainly within the next century. In the case of coal, the known U.S. resource

base--the world's largest known reserves--will be adequate for several centuries at current and projected rates of demand."

"By some criteria, federal support for synthetic fuels development also may seem to be an anomaly of current energy policy." Changes in world energy outlook are noted; in the long run, synthetic liquids and gases may become more economic than natural oil and gas. DOE continues R&D in synthetics, but the Synthetic Fuels Corporation supports "...the most promising synthetic fuels technologies using a number of economic incentives."

"Since other end-use fuel demand is projected to increase at less than the rate of GNP growth, the electricity share of final energy consumption is projected to increase during the remainder of this century."

#### Energy Security in NEPP-1983

"No aspect of the federal role in energy is more critical to our national security interests than programs in the area of energy security." Federal activity includes the SPR, the NPR, emergency preparedness, nuclear non-proliferation agreements, international trade and cooperation.

"In the event of a supply disruption, the United States will fulfill its international obligations and rely on unrestricted energy markets to distribute supplies domestically, including supplies drawn down from the SPR. Markets are far superior to any alternative way of allocating oil during supply disruptions...the U.S. approach is to rely on market forces at home and abroad and thereby demonstrate to others in our international energy relations that this strategy is in their and our mutual long-term interests."

"Although the primary threat to the collective security of the United States, Western Europe, and Japan remains our continued vulnerability to oil supply disruptions, there have been a number of changes in the world energy situation since the oil supply disruptions of the 1970s that have strengthened significantly free-world energy security."

"The overriding concern of our allies to reduce their dependence on imported oil has led to a growing reliance on natural gas from the Soviet Union, a new source of vulnerability and concern to our collective energy security."

#### NEPP-1983 on Energy Trade and Transportation

"Continued free-world economic recovery will lead to long-term growth in total energy demand. Energy demand growth, coupled with the fact that the world's energy resources and technological capabilities are not distributed evenly, will lead to the increasing importance of energy trade and related energy

transportation issues in national and international energy policy concerns."

"The market will continue to determine the level of U.S. coal exports in competition with lower cost supplies from areas such as Poland, Australia, and South Africa...coal destined for export will not be diverted to satisfy domestic demand except in the event of a national emergency."

"Current law permits exports of petroleum products, but prohibits exports of crude oil." "There are a number of important reasons for considering alternatives to the existing ban on the export of Alaskan crude oil." "Finally, the area of nuclear energy trade remains a principal concern of U.S. energy and foreign policies."

#### NEPP-1983 Energy Projections

The energy projections on which NEPP-1983 is based have been used as the core of this report. The following comments from NEPP-1983 are included to indicate the Administration view of these matters:

"...world oil prices probably will fall in real terms until the mid-1980s, barring a significant oil supply disruption. From 1985 to 1990, prices are projected to increase moderately in real terms. Beyond 1990, the outlook becomes increasingly uncertain."

"...conservation forces are likely to continue..."

"Oil price increases also provide incentives for development of energy resources other than oil."

"Investment planners must be concerned about the potential for future price breaks."

"Over the long term, and barring a decline in oil and gas prices, coal, renewables, electricity, and energy conservation steadily will displace oil and gas in stationary uses."

"Under all but extreme assumptions, the United States and the rest of the world will remain dependent to some extent on oil supplies from OPEC during the next 20 years."

Energy trends are extremely difficult to predict, probably impossible. But in NEPP-1983:

Oil prices have been projected as smooth paths. In any year, prices could be considerably higher or lower. World oil prices should fall until the middle 1980s. Beyond 1990, prices should rise faster than inflation; the question is whether slightly faster or much faster.

In 1983 and 1984, world oil prices should be \$23 to \$30/bbl in 1982 dollars, unless world economic progress changes or the

Iran-Iraq war ends.

With an expanding world economy, between 1986 and 1990, demand for OPEC oil should reach 24 to 26 million BPD, pressuring prices upward. By 1990, the price of oil in 1982 dollars should be between \$25 and \$40, about the same in real dollars as before the decline from \$34 in 1982. "Beyond 1990, world oil prices are extremely uncertain and speculative, but are projected in real terms to reach between \$36 and \$80 per barrel by the year 2000 and between \$55 and \$110 per barrel by 2010." Unpredictable events or technological changes could "...render current projections of dubious value."

"One conditioning factor influencing the projected range of price increases during the 1990 to 2010 time period is the assumption that the cost of unconventional oil sources such as shale oil and coal liquids will be in the \$50- to \$80-per-barrel range (1982 dollars) as opposed, for example, to the \$35- to \$50-per-barrel range assumed by NEP-1979."

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